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d'Enginyeria de Vilanova i la Geltrú**

UNIVERSITAT POLITÈCNICA DE CATALUNYA

# TREBALL FINAL DE GRAU

**TÍTOL: DESIGN AND DEVELOPMENT OF A SAILING WATCH**

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## RESUM

Este proyecto trata sobre el diseño y desarrollo de una propuesta para mejorar la experiencia durante la práctica de los deportes náuticos de vela. El objetivo es aportar una solución a una problemática existente en el mundo del deporte de vela, donde en el desarrollo de una competición, los deportistas tienen dificultades para obtener la información relevante para el desarrollo de la carrera.

De esta manera el proyecto empieza con un planteamiento del problema haciendo uso de la herramienta Mind Map, para posteriormente conocer el estado actual etnográfico y sus necesidades, gracias a las entrevistas realizadas y la investigación del sector náutico.

Posteriormente se realiza un estudio de las soluciones que se encuentran actualmente en el mercado y que son competencia directa del producto que vamos a desarrollar.

Una vez se ha realizado este estudio, se plantean distintas ideas para desarrollar una propuesta válida sobre la que trabajar. Cuando se ha seleccionado la mejor idea, se realiza un estudio dimensional teniendo en cuenta medidas antropométricas mencionadas dentro del proyecto, con el fin de obtener un producto con la mejor ergonomía posible.

Seguidamente se desarrolla una selección de materiales para cada elemento del producto, teniendo en cuenta un seguimiento de propiedades según la función que realicen.

Para comercializar este producto y hacerlo viable en un hipotético mercado, se trabaja en un proceso de Branding que englobe tanto la empresa como el producto.

Para finalizar se plantea cómo debería ser su proceso de fabricación, anteponiendo, sobre todo, los principios básicos de un producto sostenible y ecológico, así como el coste de la fabricación del producto, con las implicaciones que este tendría.

### Paraules clau (màxim 10):

Reloj	Vela	Cronómetro	J/80
Brújula	Tecnología	Mecanismo	Deporte
Sostenibilidad	Competición		

## ABSTRACT

This project is about the design and development of a proposal to improve the experience during the practice of sailing nautical sports. The objective is to provide a solution to an existing problem in the world of sailing, where in the development of a competition, athletes have difficulty obtaining information relevant to the development of the race.

In this way, the project starts with an approach to the problem using the Mind Map tool, to later know the current ethnographic state and its needs, thanks to the interviews and the research of the nautical sector.

Later a study of the solutions that are currently in the market and that are direct competition of the product that we are going to develop is realized.

Once this study has been carried out, different ideas are presented to develop a valid proposal on which to work. When the best idea has been selected, a dimensional study is carried out taking into account anthropometric measures mentioned within the project, in order to obtain a product with the best possible ergonomics.

Next, a selection of materials is developed for each element of the product, taking into account a followed by properties according to the function they perform.

To market this product and make it viable in a hypothetical market, we work on a branding process that encompasses both the company and the product.

Finally, it considers how the manufacturing process should be, putting, above all, the basic principles of a sustainable and ecological product, as well as the cost of manufacturing the product, with the implications that this would have.

### Keywords (10 maximum):

Watch	Chronometer	Compass	Sail
Technology	Mechanism	Sport	Sustainability
Competition	J/80		



## Index

Motivation .....	12
1. Introduction .....	13
2. Objectives .....	14
3. Analysis of the problem .....	15
3.1 Mind map .....	15
3.2 Mind map focused .....	17
3.3 Ethnographic study .....	18
3.4 Conclusions of the analysis of the problem .....	21
4. Methods of research and analysis .....	22
4.1 Interviews .....	23
4.1.1 Interview to Marta Dávila .....	23
4.1.2 Interview to Carlos Roselló García .....	25
4.2 Results .....	27
4.3 References .....	28
4.4 Study of needs of the user .....	35
4.5 Study of functionality and functions derived by scenes .....	38
4.6 Previous studies conclusions .....	39
4.7 Briefing .....	40
4.7.1 General requirements: .....	41
4.7.1 Requirements for Ergonomics .....	40
4.7.1 Safety Requirements .....	41
4.7.1 Maintenance Requirements .....	41
4.7.1 Materials requirements .....	40
4.7.1 Finishing / aesthetic requirements .....	40
5. Development of the proposal .....	42
5.1 Study of concepts .....	43
5.2 Final Proposals .....	50
5.2.1 Sketch A .....	50
5.2.2 Sketch B .....	51
5.2.3 Sketch C .....	52
5.2.4 Final proposal .....	53
5.3 Anthropometric study .....	54
5.3.1 General Anthropometric Measures: .....	55
5.3.2 Anthropometric measurements visual field .....	56
5.3.3 Hands anthropometric measures .....	57
5.4 Ergonomic study .....	58
5.4.1 Case size .....	58
5.4.2 Watchband size .....	59
5.4.3 Crown Size .....	60
5.4.4 Distribution of the elements .....	61
5.5 Dimensional proposal .....	62

5.6 Functional and usability study .....	65
5.6.1 Watch .....	65
5.6.2 Compass .....	65
5.6.3 Chronometer .....	65
5.7 Moadboard .....	67
5.8 Colour and Trim .....	68
5.9 Selection of materials .....	70
5.9.1 Selection of material for the belt .....	71
5.9.2 Material selected for the watchstrap .....	76
5.9.3 Selection of material for the case .....	76
5.9.4 Material selected for the case .....	78
5.9.5 Selection of materials of the rest of components .....	79
6. Brand image proposal .....	80
6.1 Name of the brand. ....	81
6.2 Logo. ....	82
6.3 The brand colours .....	84
6.4 Typography .....	85
6.4.1 Selection of typography .....	85
6.5 Final proposal .....	88
6.5.1 Proportions and spacing .....	89
6.5.2 Favicon .....	89
6.5.3 Readability 8 mm .....	90
6.6 Documentation .....	91
6.7 Formal proposal .....	92
7. Technical documentation .....	94
7.1 Plans .....	95
7.2 Normative .....	107
7.2.1 Rules of competition in J/80 .....	107
7.2.2 Product development regulations .....	107
8. Industrialization study .....	108
8.1 Sustainability in the manufacturing process .....	109
8.1.1 Renewable energies as an energy motor .....	109
8.1.2 The product life cycle .....	110
8.1.3 Sustainable design .....	110
8.1.4 Durable device is a greener device .....	111
8.2 Fabrication of the case .....	112
8.3 Manufacturing process of polyurethane strap .....	113
8.4 Manufacturing Process of Minor Components .....	114
8.4.1 Manufacturing of the hands .....	114
8.5 Electronic components .....	116
8.6 Clock mechanism .....	118
8.6.1. Modification of the ETA mechanism .....	119
8.7 Assembly of parts .....	120
9. Economic Study .....	121
9.1. Cost of manufacturing the parts .....	122



9.1.2 Internal elements.....	122
9.2 Amortization .....	123
9.2.2 Machinery Watch Strap.....	124
9.2.3 Machinery Handles .....	124
9.3 Hours and operators required for the process .....	125
10. Improvement proposal.....	126
11. Conclusions .....	127
12. Bibliography.....	128
Attachments .....	130

## Index of figures

Figure. 1 Mind Map of Sail Sports .....	16
Figure. 2 Mind Map Focused.....	17
Figure. 3 Marta Dávila in a Sailing Competition on the Movistar's Sailing Team .....	23
Figure. 4 Carlos Roselló practicing Sailing Sport in a J/80 .....	25
Figure. 5 References of this Brifing .....	28
Figure. 6 References of this Brifing .....	28
Figure. 7 Sketch 1, 2 & 3.....	44
Figure. 8 Sketch 4, 5 & 6.....	45
Figure. 9 Sketch 7, 8 & 9.....	46
Figure. 10 Sketch 10, 11 & 12.....	47
Figure. 11 Sketch 13, 14 and 15 .....	48
Figure. 12 Sketch 16, 17 & 18.....	49
Figure. 13 Proposal A.....	50
Figure. 14 Proposal B.....	51
Figure. 15 Proposal C .....	52
Figure. 16 Final proposal.....	53
Figure. 17 Percentiles of men and women type P25/P75 .....	54
Figure. 18 General Anthropometric Measures .....	55
Figure. 19 Anthropometric measurements visual field .....	56
Figure. 20 Measures of the fingers according to sex .....	57
Figure. 21 Measures width of the hand and wrist.....	57
Figure. 22 An oversized size can disturb the movement of the hand.....	58
Figure. 23 An oversized size may not hold the watch well to the wrist .....	59
Figure. 24 Interaction with the Crown.....	60
Figure. 25 Distribution of the elements.....	61
Figure. 26 Proportion of elements .....	62
Figure. 27 Diameter case .....	62
Figure. 28 thickness case.....	63
Figure. 29 measures watchbstrap .....	63

Figure. 30 Measures crown .....	64
Figure. 31 A. Timer Function - B. Chronograph Function - C. Compass Function .....	66
Figure. 32 Moadboard .....	67
Figure. 33 Typical Mediterranean buildings .....	68
Figure. 34 Detaill os the colour of the marks .....	68
Figure. 35 Image of the Name's Brand.....	81
Figure. 36 Proportions in the logo design process .....	82
Figure. 37 S shape inside the logo .....	82
Figure. 38 Final typography proposals .....	86
Figure. 39 Comparison between Clear Sans and Lato .....	87
Figure. 40 Logo in negative .....	88
Figure. 41 Logo on white background .....	88
Figure. 42 Proportions and spacing .....	89
Figure. 43 Favicon.....	89
Figure. 44 Readability 8 .....	90
Figure. 45 Example of letter and envelope company .....	91
Figure. 46 Example of Contact Cards. White: Front. Blue: Behind .....	91
Figure. 47 Frontal render of the watch .....	92
Figure. 48 Inclination of the elements .....	92
Figure. 49 Lateral render of the watch .....	93
Figure. 50 Back render of the watch .....	93
Figure. 51 Sustainability in the manufacturing process.....	109
Figure. 52 Use of renewable energy as the main source of energy .....	109
Figure. 53 Closing the loop in the supply chain.....	110
Figure. 54 machining by CNC .....	112
Figure. 55 Manufacturing process of polyurethane strap .....	113
Figure. 56 Hands of the Breitling brand.....	114
Figure. 57 Boule obtained after the cooling cycle .....	115
Figure. 58 Union of a processor and a compass chip .....	116
Figure. 59 Chip Asashi Kasei (AKM).....	117



Figure. 60 Mechanism ETA 2802-1.....	118
Figure. 61 Assembling the details of a watch.....	120

## Index of tables

Table. 1 TAG Heuer Connected Modular 45 Specifications.....	29
Table. 2 Garmin Quatrix 3 specifications .....	30
Table. 3 SUUNTO Elementum Ventus specifications .....	31
Table. 4 Omega Seamaster Diver 300M ETNZ specifications .....	32
Table. 5 Tissot t-touch expert specifications .....	33
Table. 6 Slim d'Hermès Quantième Perpétuel specifications.....	34
Table. 7 General percentiles by sex .....	56
Table. 8 Visual Field Angles .....	56
Table. 9 Percentiles of the hand and wrist .....	57
Table. 10 External elements cost .....	122
Table. 11 Internal elements cost .....	122
Table. 12 Complementary elements cost.....	123
Table. 13 Case and crown machine cost .....	123
Table. 14 Machinery Watch Strap Cost.....	124
Table. 15 Machinery Handles Cost .....	124
Table. 16 Timing of operators in the assembly process .....	125

## Motivation

When I came up with the idea of doing a final grade project focusing on the proposal of a product, the possibility arose of working and investigating in various fields that throughout the race that wanted to enter but for one reason or another was never possible.

For this development I had the total freedom to be able to do what I always wanted, and at last came the opportunity to embark on the world of watch design. A world with many years of tradition and a huge number of companies behind each product.

I have always seen sailing sports from afar, and the previous research for the development of this work is a key point to approach a sport that I have always admired and wanted to know.

As for the brand, it is one of the two most enjoy doing, so from the beginning was clear that wanted to develop a personal brand. Make the product as possible as possible and with all the professionalism that I would ask for in a design



## 1. Introduction

Throughout this work, will be tracked of the creative process of the design and development of a product that seeks to solve an existing problem in the real world. In this case it is an improvement for water sports with a device that give useful information to the user in the practice of sailing sports.

In this process will see how the problem to solve is presented and how the different ideas to solve the problem are developed, through sketches and ideas that can be carried out.

In addition, with the graphic image both of the product and the company formed to realise this product, with a thematic background that will be very marked by the maritime environment. This graphic image includes both the corporate colours and the iconography in the company's office material. This is a very important part of the development, since these colours will position the product in one sector or another.

## 2. Objectives

The initial objective of this project is the design of a product that improves the experience of sailing sports. To do that, it will give information service to the user according to the needs of the moment.

This product will be in a maritime environment, so it will have to have a series of characteristics that make it resistant to the water and the blows that occur in the performance of this product.

In addition, it has to be accessible und intuitive in the use, so as not to disturb the athlete in the practice of the sport. Therefore, it will be essential that great gestures are not required to consult the information provided.

Another objective for this device is that it must be complement in the day to day. It means, that it should not be an exclusive device in the practice of the sport and it can be used in everyday life as a complement. That give a more personal character to the product and increase the user's need to depend on it

### 3. Analysis of the problem

As mentioned in the introduction, the objective of this work is to solve the current problems that users who practice sailing sports, who need a system of accurate and fast information while doing this sport

To do that, is needed to be in consideration different factors, insomuch as the sport of sailing is governed by restricted rules and there are a number of prohibitions depending on the category of the boat. For example, the boats of 4/20 can't be connected to internet and only can use the information offline, on the contrary in the boats J/80 that is allowed the use of internet connection.

According to the study realised in the elaboration of this project, there are a number of parameters that are crucial for navigation, and these are timed time, boat direction and wind direction.

Putting in situation, during the realization of this sport is very difficult to have this kind of information in a comfortable and accessible way. Different elements have to be used to obtain detailed information, and during the consultation of this kind of equipment it consumes time of one of the members of the boat.

In this way, a system that allows to show the information into a precise way and very accessible, could improve the user experience and would give an added bonus to the embarkation thanks to dispose of this information in an easiest way than the rest of the teams

#### 3.1 Mind map

The next step for the design of the project is the realization of a Mind Map where to capture the different concepts that surround the work. To do this, a central theme arise and leave elements that are divided into themes and later into ideas.

To the elaboration of the first Mind Map, was used the Nautical world as the main theme and the question to solve was: What can I bring to seal sports?

Then the following main branches emerged:

- **Navigation:** Elements that influence the navigation
- **Crew:** Items related to crew on board
- **Information:** what type of information is queried during a race
- **Competition:** Aspects that appear in the competitive world of sailing boats.
- **Ship:** Elements that directly affect the boat.

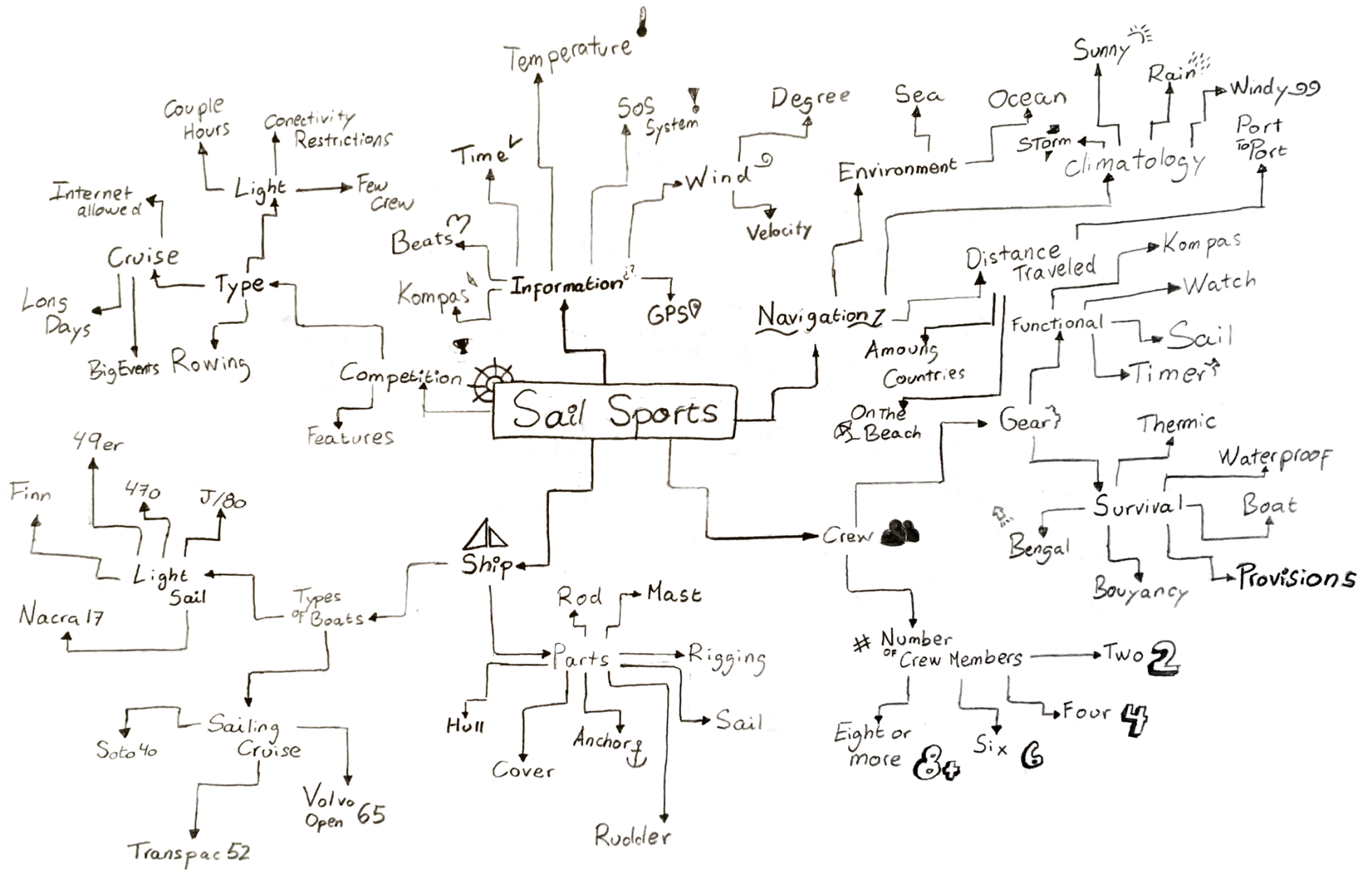


Figure. 1 Mind Map of Sail Sports

### 3.2 Mind map focused

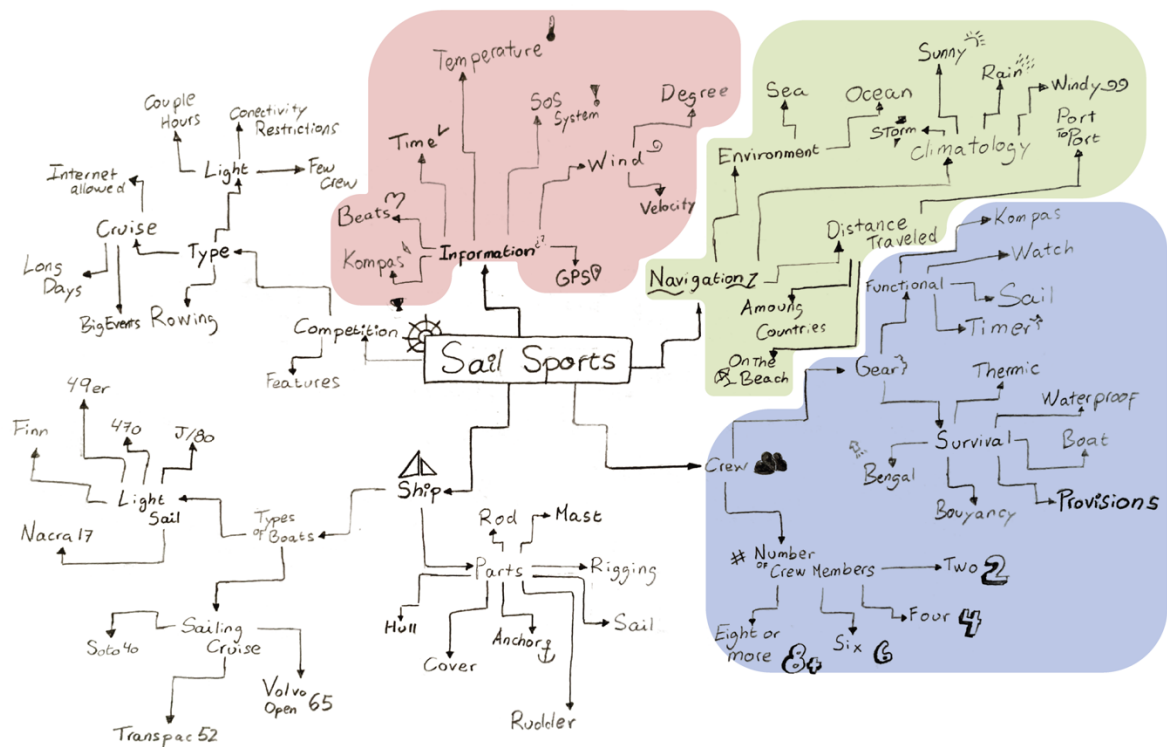


Figure. 2 Mind Map Focused

Once you have done the mind map, you have to analyze it in order to get the necessary information to develop the project, for this we will focus on the three branches that we can extract the most useful information, these are:

**Information:** As mentioned in the previous section, the problem that we want to solve with the development of our product is the visualization of information while practicing sailing sports. So this is one of the most important branches in order to get what parameters we can find in navigation.

**Navigation:** Another important area is navigation itself, which gives us information about the elements that we can find when we think about navigation, as well as the environment, climatology or distance covered, which clearly influence the navigation experience.

**Crew:** Finally the crew. Mind map branch that gives us information about the elements that are used in a boat of these characteristics and the division according to the crew of the boat.

### 3.3 Ethnographic study

In order to find a solution to the problems raised, it is necessary to know the situation and to know in depth the environment in which this problem is involved. For this, a brief study is carried out in order to know the characteristics of the nautical world.

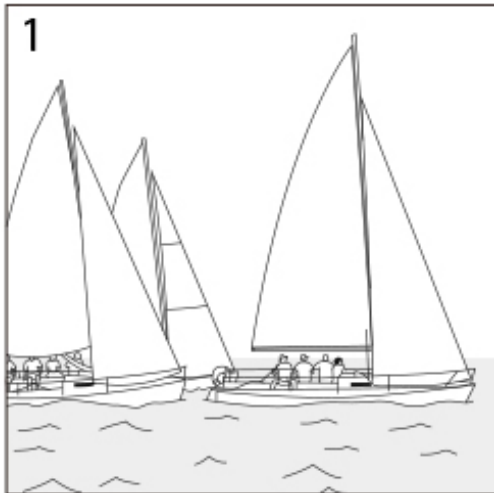
Different devices are currently used to follow a series of vital parameters during navigation. As mentioned in the previous sections, this study will focus on light sailing competitions with J/80 boats. Since it is a type of competition that allows the use of more external aids and limits the use of tools less.

Therefore, in this type of competitions, the most important parameters and to take into account in navigation are the following:

- **Timer** set to 5 min easily and quickly, as it is the time available to prepare the boat in sailing dinghy racing. This timer also has a way to dial when a minute is missing for the countdown. At this time the boat must remain still while it is pivoted to decide the strategy with which it is going to leave.
- Indicator of **speed and direction of the wind** of precise way, so that it shows the direction of the wind with up to three digits of information. A slight change can completely change the team's strategy at sea
- **Precision compass** that marks a past position. This means that if you make a change of course, you should know from which direction you left to perform the manoeuvres in comfort. Also it is necessary to take into account that this precision is very important since it is not the same to go  $5^\circ$  towards the north that  $10^\circ$  toward the same north.

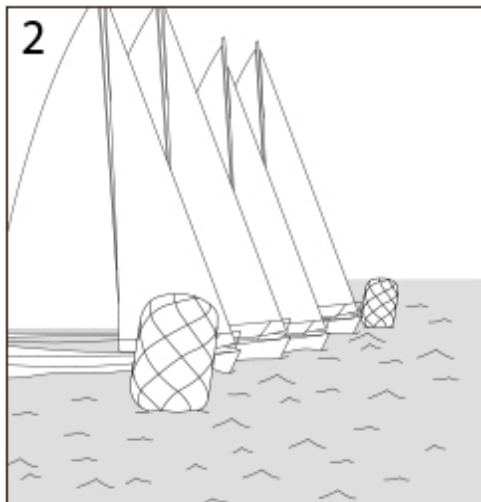
Most of these parameters are taken into account in the previous 5 minutes prior to the start of the competition, where participants prepare their boat in the current weather conditions.

To explain the current state of a sailing regatta a mind map (fig X) will be made, detailing the steps to follow before regatta.



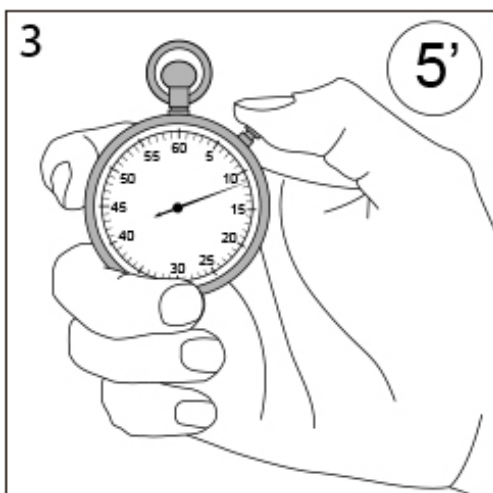
**Image 1:**

Participants leave the beach on the high seas



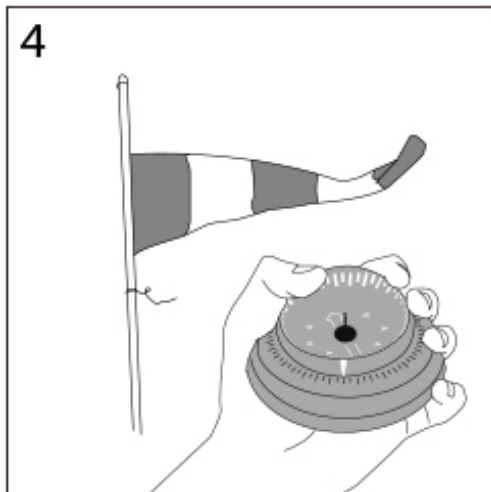
**Image 2:**

Two large buoys await at the sea, which will act as starting lines. It is very important not to exceed this line because it could be considered a reason for disqualification. It is also important to be as close as possible because according to the initial position will have a better position for the wind



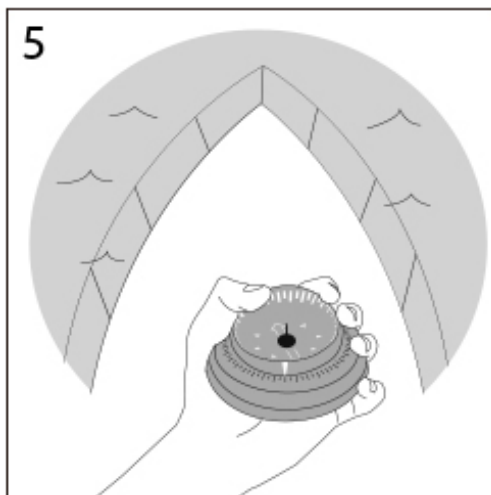
**Image 3:**

The organizers give the beep of preparation. It is then that the participants have 5 mins until they start giving the start of the race again. This time is crucial since it is the one that prepares and organizes the next strategy of the competition. Another time to keep in mind is when there is 1 min, as a warning to sailors



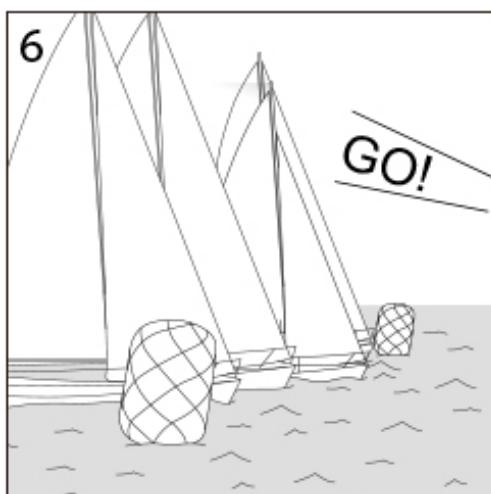
**Image 4:**

In these 5 min you look at the direction and speed of the wind. It is very important to know where you come from so that you can take advantage of the best positions and get the job done. The boats that receive the most wind are the ones that cause the most difficulties to the opponents since the sails make of screen. That's why both our position and that of our opponents is so important.



**Image 5:**

The last parameter before starting the competition is the direction of the boat. It is the least seen before beginning, but the most watched during the race.



**Image 6:**

The starting gun kicks off and the competitors start the regatta. It is very important the positioning to get the best wind and make the route as straight as possible with the wind in favour.



### **3.4 Conclusions of the analysis of the problem**

After analysing the current state and the problem, we can conclude that a regatta is determined by a lot of parameters that are evaluated with different devices with a high precision.

Devices such as the compass, make it difficult to use on the high seas due to the great pressure that is being subjected to a regatta and the difficulty to consult your information quickly and conveniently.

In addition, in some competitions like those of boats J / 80, the use of Internet connectivity is allowed, reason why the conventional apparatuses are short before the new technologies.

A comfortable and connected device, could give more information more quickly and effectively.

## **4. Methods of research and analysis**

## 4.1 Interviews

In order to understand the real needs of users and then to be able to understand how a solution can be given, their opinion is very important. For this reason, three interviews have been conducted with different types of users:

- Marta Dávila
- Carlos Roselló García

### 4.1.1 Interview to Marta Dávila



*Figure. 3 Marta Dávila in a Sailing Competition on the Movistar's Sailing Team*

For the first interview we have the participation of **Marta Dávila**, a sailor who has been linked to the sailing competition since the age of 12 and was the **winner of the lightweight sailing world in 2014**. She is currently sponsored by brands as important as **Red Bull** although it is no longer so closely linked with this sport because of its studies.

#### **What is your link with the nautical world today?**

At the moment I choose the competitions in which I want to compete, and when there is a major championship a new contract with the current sponsor is signed according to the level of availability and they are in charge of giving the support so that it can compete

#### **How do you plan a sailing session?**

It all starts a week or two before, since you have to go to plan the championship and train to get accustomed to different factors such as the type of wind, the type of tides, how the waves are there, the buoyancy theme of the water makes the boat float more or less and that influences the speed), as the tides change, etc.

**What preparation do you do before a race?**

They leave you half an hour to go to the course and regattas which are usually 20-30 min. You take the exact blueprints and every 5 min takes measured wind direction to know how this varies. While testing different speed tests, etc. When you have 5 min you have to position yourself between a buoy and an imaginary line that will be the starting line where the position is crucial. The time is very important because if you start a second later, the boats are positioned better and you block the wind line. During this time, you plan your strategy according to your position and that of the opponents.

**What is your role in the boat?**

My role is strategy, on which side there is more wind, what would be the overall strategy of the regatta, the speed of the boat in terms of sailing, etc. She looks more locally at what actions the ships that are nearer perform.

**What factors influence navigation?**

The initial position in the race, because if you go ahead you are affected by the wind changes, so the wind degrees are very important. Another factor is the pressure, more wind. Then the positioning of the rivals as they cover the wind.

**What elements do you use during navigation?**

The two most important elements are the compass and a stopwatch. The compass because both degrees of wind and navigation are very important, this must be very precise since one degree can make the difference. The second is the stopwatch, since it is very important to start on time, as every second counts.

**How are the restrictions in a race?**

According to the boat you are allowed to carry some items or others, for example in the boat that I participated, light sailing, you are not allowed internet connection. This limits you to the time of looking at tides, the changes of the wind, etc. Then it is very important to know the target audience because it is affected by the regulations.

#### 4.1.2 Interview to Carlos Roselló García



*Figure. 4 Carlos Roselló practicing Sailing Sport in a J/80*

Carlos Rosello has been in the nautical world since he was very young. He was born and raised on the small island of Formentera (Ibiza), although he now resides in Valencia, where he has not left his passion. Currently, he competes aboard a J/80.

#### **Could you tell us what tools you consider indispensable for navigating in the J/80 category?**

In the category where I compete, J / 80, the regulation restricts us a lot the use of devices to navigate. This depends on each category and we only allow the use of a compass and a stopwatch. The witch is a Garmin Silva, which is quite accurate. And the chronometer is not so important because with any one that allows you to keep accounts behind is more than enough. Other categories do use a lot of different devices, from GPS, to systems that tell you the direction and speed of the wind at all times. We have this much more restricted.

#### **Throughout your experience, what do you think are the keys to a victory in competitions of this style?**

There are several factors that determine who is the best in a competition, but the most important factor is the strategy, especially of placement and anticipation regarding your opponents. In a category of this style where everyone plays with practically the same tools, making the difference becomes really difficult. That is why the placement of the boat at key moments of the race makes the job a lot easier, although we have to be there, in the place of the biggest wind in favour, and that is what we all want.

**With all kinds of boats, do you usually compete in more than one?**

The truth is that sometimes it is difficult to compete for other categories, because budgets are usually very high. But over the years one gains experience and knows people with whom you can collaborate to participate in other categories. And this from time to time goes very well to change the way we think and leave our comfort zone. The strategies and equipment that are used in a category can become much more different than it seems at first glance. And having experience in other competitions is always something positive.

**What are the most important aspects beyond the strategy you need to be competitive?**

Basically there are two pillars: the state of form and equipment. The state of form is not recommended; it is necessary to win seconds. We manage boats, which may be bigger or smaller, but we will always be competing in a race to be the fastest, and with it the one that performs the manoeuvres faster has more numbers to take the victory. On the other hand, equipment, since every second counts, and the time you lose consulting information is valuable time, you lose in the form of investment, to manage a career.

**One aspect I'd like you to tell us about is how you think technology has affected sailing.**

Some time ago I read an interview where a sport such as football and sports related to sailing. Over time, more and more accurate data are collected. This makes it possible to keep track of many factors that were previously almost unattainable. From knowing the pulsations at every moment during a race, to the state to the millimetre of the climatology. I am of those who think that technology has come to stay and change all sports, where more and more statistics are used thanks to the large amount of data that is collected and that makes the way to sail for years, is light years of how we navigate today.

## 4.2 Results

After the interviews, we analyse the different responses that have given us the users. Each of them also has a different point of view.

In these interviews you can put yourself in position and know first-hand how the regattas world is and the elements that surround them.

We are faced with a great variety of parameters of extreme precision and a lot of normative different according to the type of boat and the type of competition.

Following the advice by the interviewees, has gone into detail the environment for which will be realized. In this way the product will be designed for J / 80 boats because they allow a minimum of elements and connectivity to make this type of competitions, and are not very large boats that require other more precise tools

In general, and as a conclusion, the objects most used in the regattas to obtain this type of information are the watches. Whether it's traditional or new smartwatches that have hit the market. Each of them with its advantages and disadvantages.

One of the key factors of traditional watches is the personal feeling you have towards them. These are not mere functional objects, even they are not just aesthetic objects. They go beyond and are representative objects of the person that define their lifestyle and their way of being.

In this way it is further defined how the product has to be and what functions it must have in order to be rally functional.

One of the key points will be the internet connectivity that will allow to show through a 3G connection the different parameters with greater accuracy than with an Analog System.



### 4.3 References

The next step is to analyse the different solutions that are currently in the market. For this analysis is to take into account both smartwatches and traditional watches, but the common point that they have to have one that includes the functionalities useful for a regatta.

On the side of the stylish watches with Suunto brand watches, Garmin and TAG Heuer, the first two provides much needed information and the specification for sea sports also of the simple but slightly configurable modules. The third is the first bet of the Swiss traditional watch brand by the System. This allows you to install applications of all types that express their functionalities

On the other hand, there are classic watches with functions designed for regattas, such as those of the brand Omega and Tissot. These are a little more modern and have touch screen in addition to connectivity for different uses.

The ultimate comparison watch is a luxury watch that includes a series of cards that differ from the information. It is the one that has less relation to the maritime world, but the arrangement of the spheres and the aesthetics of this watch, make it have a gap in this comparison.



Figure. 5 References of this Briefing



## TAG Heuer Connected Modular 45

The first big bet of the manufacturer of sports watches TAG Heuer in the market of Smartwatches. This is a concept of eternity in which the buyer buys a Smart Watch with Premium materials common to the brand (A body of Titanium of grade 5, and a Crystal with Sapphire), so that later, with the passage of the time, the user can change the interior for a traditional watch. With that way, TAG Heuer ensures a long life of the product.

It has sensors characteristic of the smart watch like the solutions in the current market, as can be the accelerometer, gyroscope and GPS system, among others. This allows you to use this watch with the applications available in the Google Play Store, as a complement in navigation.

### Advantages

It has the Android Wear Operating System, which allows access to the great Marketplace of applications for the Google System. In addition to a pretty complete connectivity.

### Disadvantages

For the price it offers, it is short on features of Smart Watch with a mediocre autonomy. It remains to be determined if the replacement by a traditional clock interior demands pay again.



General	
<b>Fabricant</b>	TAG Heuer
<b>Model</b>	Connected Modular
<b>Price</b>	1.600-2.500€
<b>Material</b>	Titanium grade 5
<b>Crystal</b>	Sapphire of 2,5 mm
Measures	
<b>Diameter</b>	45 mm
<b>Thickness</b>	13,75 mm
<b>Screen</b>	1.39 inches AMOLED
<b>Resolution</b>	400 x 400
Technology	
<b>Processor</b>	Intel Cloverdale Peak
<b>RAM</b>	512 MB
<b>Memory</b>	4 GB
<b>Sensors</b>	Accelerometer
	Gyroscope
	Microphone
	Vibration
	GPS and NFC
<b>Connectivity</b>	Bluetooth BLE 4.1
	Wifi 2.4 GHz 802.11 B/G/N

Table. 1 TAG Heuer Connected Modular 45 Specifications

### Garmin Quatrix 3

Garmin is a famous brand dedicated to make accessories to the sports. In this case the model Quatrix 3 is a smart watch designed for nautical sports. This product has a body of stainless steel and a multiple function thanks to the connectivity.

That functions can be: a fish catches counter and a timer for racing, a race timer, start line and tack assist for sailing, plus an anchor notice to alert you of drift. It provides smart notifications for emails, text messages and more. Also includes live activity monitoring and multisport functions for races, hiking, swimming, etc.

#### Advantages

The multiple functions designed only to regatta races, in addition to golf, cycling, and running functions.

#### Disadvantages

The design and the materials can be improved. You can't install additional applications, so you have to settle for what you offer as standard

General	
Fabricant	Garmin
Model	Quatrix 3
Price	599,00 €
Material	Stainless Steel
Weigh	85g
Water Resistance	10 ATM



Measures	
Diameter	51,5 mm
Thickness	16 mm
Screen	30,4 mm
Resolution	218x218
Technology	
RAM	32 MB
Sensors	Accelerometer
	Gyroscope
	GPS and ANT
Connectivity	Bluetooth BLE 4.0
	Wifi
Battery	Lithium-Ion 300 mAh rechargeable
Autonomy	50 hours in UltraTrac mode; 20 hours in GPS mode; 6 weeks in clock mode
S.O.	Garmin S.O.
Functions	Timer, Virtual Output Line, Turn Assist, Man Overboard, and Barometer

Table. 2 Garmin Quatrix 3 specifications

## SUUNTO Elementum Ventus

Another smart watch alternative with functions designed for sailing. In this case of Suunto's brand. A watch made in Finnish with a stainless steel case and a sapphire crystal. It has a trend graph of barometric pressure, a navigation timer, chronograph and 3D compass.

All the clock controls are distributed between the buttons on the right side (A, B and C Fig. X). Also, to switch between the options included, we must keep pressing one of these buttons to change modes.

### Advantages

Very complete functions with the information necessary for navigation. Economical price for a watch of these characteristics.

### Disadvantages

Complexity when calibrating the compass. Unattractive design for day to day.



General	
<b>Fabricant</b>	Suunto
<b>Model</b>	Elementum Ventus
<b>Price</b>	700€
<b>Material</b>	Stainless Steel
<b>Crystal</b>	Sapphire
<b>Weigh</b>	95 g



Measures	
<b>Diameter</b>	45 mm
<b>Thickness</b>	13,75 mm
<b>Screen</b>	1.39 inches AMOLED
<b>Resolution</b>	400 x 400
Specifications	
<b>Saling timer</b>	60 minutes
<b>Waterproof</b>	100 m
<b>Batery Type</b>	CR2032
<b>Battery life</b>	1 hour in normal use
<b>Sensors</b>	Barometric pressure
	Gyroscope
	3D compass
<b>Compass resolution</b>	1°
<b>Max. tilt angle</b>	45°

Table. 3 SUUNTO Elementum Ventus specifications

## Omega Seamaster Diver 300M ETNZ

Since 1998 the Omega brand sponsors the Emirates Team New Zealand sailing team. With this patronage in mind came this clock. Includes two types of chronograph; One of them thought for regattas and a chronometer.

In addition, it has a unidirectional rotating ring, in matte black ceramic, with a scale of immersion, polished and with signs carved in relief by laser. Being unidirectional, the user cannot be wrong while doing the diving.

It is a premium quality watch that has the seal of the official institute of Swiss chronometers. This quality is reflected in the high price.

### Advantages

Chronographs of high precision and remarkable quality of the product

### Disadvantages

It does not include essential functions for the regatta as the compass or wind indicator. The price is too high

General	
<b>Fabricant</b>	Omega
<b>Model</b>	Seamaster Diver 300M
<b>Price</b>	6.400€
<b>Material</b>	Titanium
<b>Crystal</b>	Sapphire of 2,5 mm



Measures	
<b>Diameter</b>	44 mm
<b>Thickness</b>	13,75 mm
<b>Screen</b>	1.39 inches AMOLED
Specifications	
<b>Waterproof</b>	30 bar
<b>Characteristics</b>	Chronograph
	Chronometer
	Date
	Racing Chronograph
	Bolted crown
	Small seconds
	Unidirectional rotating bezel

Table. 4 Omega Seamaster Diver 300M ETNZ specifications

## Tissot t-touch expert

Tissot presents an alternative of vitaminized clock with a digital screen in the inferior of the sphere, and with tactile functions.

In this way, the Tissot watch has different modes thanks to the connectivity it has with the mobile app of the brand itself. If we skip the screen in GPS mode, the clock will synchronize with the mobile by switching to a special mode where the clock will tell us the direction to follow, and the digits of your screen the distance we have left to make a change of course.

Another feature is that it allows us to know the weather, as it connects to the information offered by the nearest station to give the highest accuracy of the weather.

Altimeter, Chronograph, chronograph, watch find function ... etc. All this are possible functions thanks to your app and our smartphone.

### Advantages

It offers a lot of data in a very ingenious way. These data are not common in an analogy clock

### Disadvantages

Total dependency with the Smartphone app.

General	
<b>Fabricant</b>	Tissot
<b>Model</b>	T-touch expert
<b>Price</b>	970€
<b>Material</b>	Antimagnetic titanium
<b>Crystal</b>	sapphire crystal



Measures	
<b>Diameter</b>	45 mm
<b>Thickness</b>	13 mm
<b>Weight</b>	71 g
Specifications	
<b>Waterproof</b>	10 bar
<b>Functions</b>	EOL
	Meteo
	Altimeter
	Slope calculation
	Compass
	Race
	Countdown
<b>Battery</b>	Renata LMR2016

Table. 5 Tissot t-touch expert specifications

### Slim d'Hermès Quantième Perpétuel

This is the only watch not intended for regattas in this comparison, but contains informative elements useful for day to day and these can help into a regatta. In addition, it can an example of the positioning of information elements available.

The watch Slim de hermes, quantième perpétue, contains four inner spheres that show 4 different information: The left sphere indicates the year and the month; The lower the time in another time zone; The higher the day of the month and the right the lunar phases.

#### Advantages

A supplement with this price represents a social status and a lifestyle with premium quality. It becomes the object that defines you as a person. This gives you exclusivity in a social environment

#### Disadvantages

A very high price that few people can afford. Their functions are not quite useful in a regatta

General	
<b>Fabricant</b>	Hermès
<b>Model</b>	Quantième Perpétuel
<b>Price</b>	38,900€
<b>Colour</b>	Rose gold
<b>Crystal</b>	Sapphire
<b>Strap</b>	Alligator leather

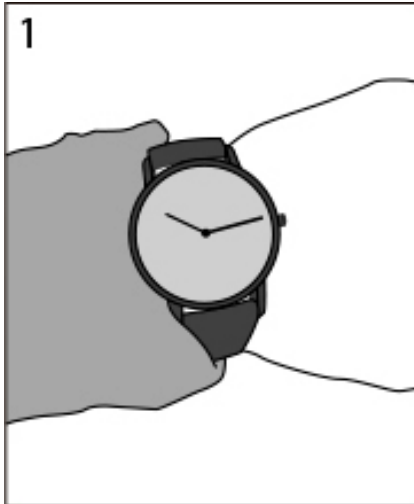


Measures	
<b>Diameter</b>	39 mm
<b>Thickness</b>	13,75 mm
Specifications	
<b>Information</b>	Year and month
	Time in another time zone
	Lunar phases
	Day of the month
<b>Manufacture</b>	Hermès Manufacture H1950
<b>Waterproof</b>	3 bar
Material	
<b>Interior</b>	316L steel
<b>Exterior</b>	750 gold (75% pure gold, silver, copper or palladium in variable proportions)
<b>Diamonds</b>	Top Wesselton
<b>Other</b>	950 Platinum

Table. 6 Slim d'Hermès Quantième Perpétuel specifications

## 4.4 Study of needs of the user

The next step is to analyse the needs that are in the current state of the product. To do this, a storyboard will be created, outlining the needs of the watch. In this way, following the storyboard the needs that can be detected are the following:



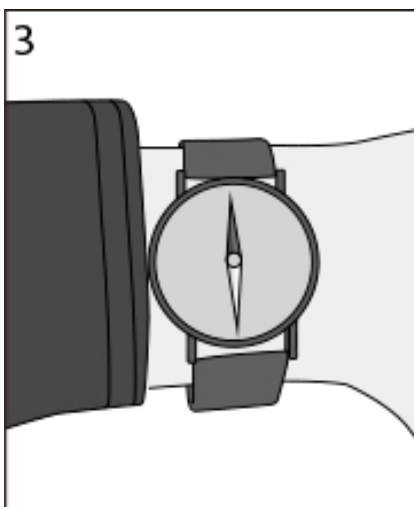
**Image 1:**

- The user should be able to check the time quickly
- The user must be able to read the time information even in conditions with poor visibility
- The user must be able to see the exact time accurately



**Image 2:**

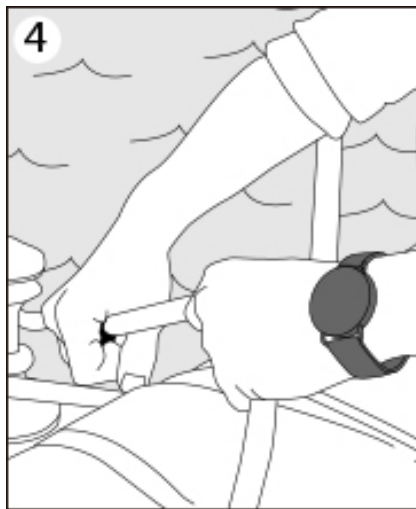
- The user must be able to see the hours, minutes and seconds elapsed
- The user must be able to see information quickly
- The user must be able to view the timer information even in poor visibility conditions
- The user has to: to trigger, to stop and to revive the time quickly
- The user must be able to use the timer intuitively



**Image 3:**

- The user must be able to read geographic information quickly
- The user must be able to read the information in poor visibility conditions
- The user must know what information the needle is marking
- The user must be able to know the exact grades
- The user must be able to switch easily from one mode to another





**Image 4:**

- The user must be able to perform all types of tasks and / or manoeuvres in the boat
- The user must be able to perform these tasks comfortably
- The user should feel comfortable using the product



**Image 5:**

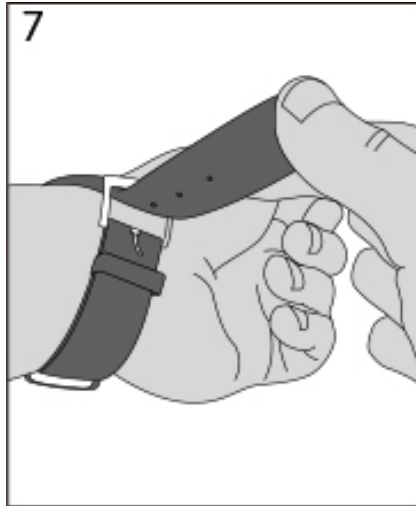
- The user must be able to submerge himself with the watch, in both freshwater and salt water
- The user must be able to consult and / or use the various functions of the watch inside the water



**Image 6:**

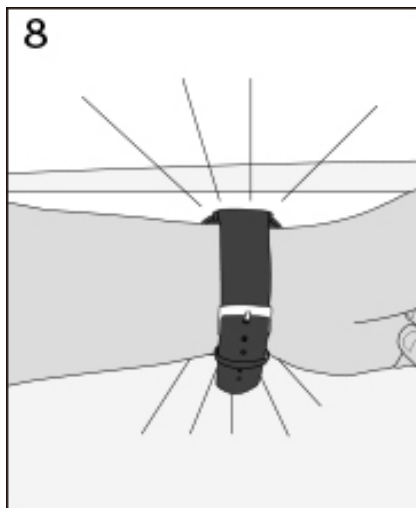
- The user must be able to carry it in the day to day
- The user must be able to have a personal feeling towards the object





**Image 7:**

- The user must be able to adjust the watchstrap.
- The User should be able to strap easily
- The user must have ideal holes tailored to his wrist.
- The user should feel like with the bracelet
- The user does not have to feel pain or discomfort due to its use.
- The user should not have allergic reactions when in contact with the material of the watchstrap.
- The user must be able to hide the leftover watchstrap so that it does not interfere with its use.



**Image 8:**

- The user must be able to ignore the possible blows in their daily use.
- The user must be able to feel safe when using it.

## 4.5 Study of functionality and functions derived by scenes

In this section we will study the functions that the watch has to fulfil as a product according to the scenes derived from the scenes.

### Image 1

The watch must be able to show the time in front of any type of light

The clock should show the time information of a clear way

### Image 2

It should be possible to start and stop the stopwatch in a quick way

The clock has to indicate seconds and minutes

The clock must have a mode to pause the timed time

### Image 3

It should be clearly identified where it indicates the north

The degrees of difference should be clearly displayed

It is necessary to know the previous position to see the turn made

### Image 4

The watch should be a light complement

The watch should be a comfortable object

The watch must be attached to the wrist

### Image 5

The watch must be waterproof

The watch should not lose its functionalities in the water

### Image 6

The design of the watch should be elegant

Clock design should be discreet

The clock must be an object that generates a good social status

### Image 7

The strap should be adjustable to the user's wrist

It must contain closing points with a distance between them

Leftover watchstrap should not disturb

### Image 8

The body must be resistant to everyday blows

The glass must be resistant to scratches

## **4.6 Previous studies conclusions**

During the previous sections we started by choosing an environment with a Mind Map, we studied the current state to look for a possible problem to solve based on the interviews of real users, later we looked at the references that we can find at present that try to solve said problematic. With this information we extracted the needs that are presented in the environment that we want to launch our product to later create a briefing according to the points mentioned above, which allows us to find the most appropriate solution to the problem raised.

In this way we conclude that the user needs a product with which he can carry out the different activities related to the sailing competition, without interfering in his development, allowing him to obtain data that improves his experience during a race.

That is why it has been decided that the most suitable product to solve this problem is found in a clock, because this allows you to consult the information as quickly and efficiently as possible, while leaving the hands free to the user to be able to handle the boat.

It has been seen as currently present very valid solutions that are based on technological screens that show all kinds of information very interesting, but that have many negative points, such as the aesthetic that is usually not the most successful, or the charge of needing a battery for its daily operation.

This is intended to find a product that does not rely on batteries in the short term, and that can show the most essential information during a regatta, and based as one of its pillars, the aesthetics of the nautical world of competition.

## 4.7 Briefing

Once the environment and the needs have been studied, it is time to make a list of needs that the product must meet. This list must be as detailed as possible and with a justification accordingly.

### 4.7.1 Materials requirements

**Recyclable:** The materials to be used must be able to have a second life

**Water Resistant:** Due to the long time in contact with water, the selected materials should not be degraded by contact with this material.

**Without nickel presence:** Nickel is a metal found in many metal alloys. The presence of this material causes allergies to the user when in direct contact with the skin, in addition to increase its effects by the sweat. It is essential that the material used for the watch does not contain this element.

### 4.7.1 Requirements for Ergonomics

**Comfortable watchband:** The user experience of the watchstrap should be comfortable; this is achieved with a size suitable for the user's wrist. Possible thanks to a previous anthropometric study.

**Easy manoeuvrability of the crown:** An element so small that it is going to make much use, should be comfortable for the user. That is why design and size is a key point.

### 4.7.1 Finishing / aesthetic requirements

**Classic design:** One of the requirements when designing the watch is that it does not include its information on any type of screen. In this way it is sought to maintain the appearance of a classic watch.

**Premium Quality:** The quality of construction should be premium, since it is focused on a sector of high purchasing power

**Maritime style:** The design of the watch should be able to be related to the maritime environment. Whether for shape or elements, as for their colours.

#### 4.7.1 Maintenance Requirements

**Battery change every 12 months:** The technology used by the watch must have a very low power consumption, allowing its operation with a battery. This should last up to 12 months so that the user can be unconcerned about maintenance during that time.

#### 4.7.1 Safety Requirements

**Submersible:** It can be submerged in the sea and resistant to the blows that happen both in the day to day and in a day of regatta

**Resistant Crystal to impact and bruising:** Due to its use in sports environments, the watch glass must be able to withstand the blows caused during its use

**Watchband:** It must give security in its use, that during the movement of the hand it remains firm.

#### 4.7.1 Other requirements:

**Production cost 250 €:** Has been established 250€ as maximum, for the cost of production

**Weight < 150 g:** The wearer should not wear out the wrist watch for prolonged periods of time. You should be comfortable all day long

## **5. Development of the proposal**

## 5.1 Study of concepts

After the study of the product and defined the needs to achieve. It is time to propose different models to reach the final proposal. It is possible to say that these proposals do not have to fulfill all the requirements, since between them, later they can be complemented. This gives more freedom when looking for proposals.

In this way, the initial sketches are based on basic ways of approaching the product, without having to have all the appropriate data. With the passage of the sketches, the concept will become more and more defined, as well as adapting more and more to the needs studied in the previous sections.

Once the first sketches have been made, the three sketches most appropriate to the problem will be chosen that can provide a solution.

From these sketches will be worked in more detail until choosing the final sketch.

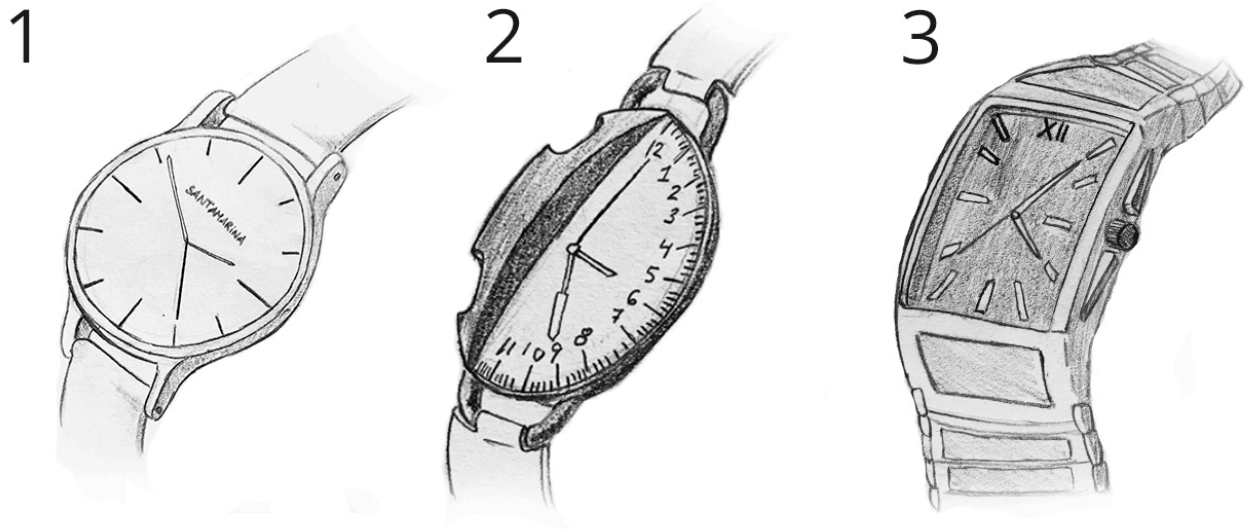


Figure. 7 Sketch 1, 2 & 3

**Sketch 1:** The first idea is that of a basic clock, which has the minimum to fulfill its function of setting the time. As problematic when choosing a watch of this style for our case we have it is a watch with fragile look, which does not convey the feeling of being ideal for a racing environment and elite competition.

**Sketch 2:** The idea of this outline consists of a clock that marks the hours using only half of the route. So when a needle has to return to its start, it will quickly return to the starting position and start again from the beginning.

It is a curious way to see the time, in addition to using a design in the form of an oval, integrates the whole mechanism in the left half of the watch. As well as the buttons to change the time.

**Sketch 3:** Another one of the sketches that represents an idea of the most common. In this case it is a watch with strap and housing of stainless steel and with housing in rectangular form

This proposal also proposes the provision of elements in the form of buttons on the side of the clock, as possible ideas on how the future user interaction with the clock could be, since the final clock will have to have the functions previously studied (Stopwatch, compass and clock).



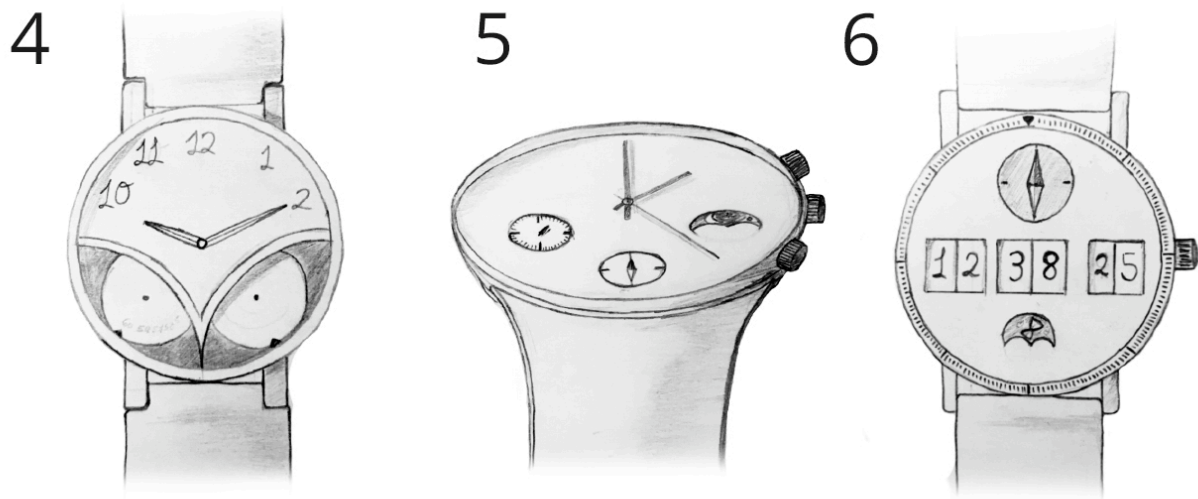


Figure. 8 Sketch 4, 5 & 6

**Sketch 4:** This proposal consists of 3 different spheres where the two spheres at the bottom rotate to mark the position marked by the arrow. These would be located under the mother dial that would mark the hour as normal clock, while the two small ones would mark the time in the form of a stopwatch and the direction of the compass respectively.

In this way the three elements could be visualized at the same time in a not so conventional way using the rotation of spheres to mark a point.

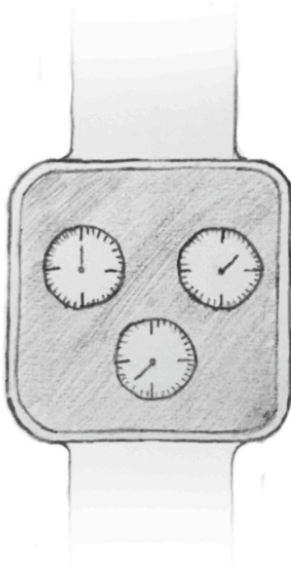
**Sketch 5:** One of the more minimalist proposals, it contains 3 small spheres that mark the chronometer, the compass, and a half sphere that marks if the hour marked in the big sphere corresponds to the day or the night. Contains 3 crowns on the right side that allow to use each crown for a different function.

In addition, the way of attaching the belt to the casing allows the maximum possible clamping, in the case of a plastic belt.

**Sketch 6:** This proposal introduces the concept of displaying the information with rotating spheres that when rotating show a number. In this case there is a lower dial that marks you if the information shown is about the time or the stopwatch. In the upper sphere we find a small sphere with a compass.

It is a proposal focused on the layout of the elements and the most effective way to show different type of information in the same element. As a negative point we find the lack of accuracy in the compass in such a small space.

7



8



9



Figure. 9 Sketch 7, 8 & 9

**Sketch 7:** Proposed inspired by the shell of the apple watch, square shape showing spheres with different types of information. These, in turn, remind us of the old command-lines of the aircraft, which showed the information in much the same way.

In this case these spheres would be the basics: One would indicate the time, the other would be used as a stopwatch and the third as a compass indicating the north.

Within the problematic that implies the little precision to be very small spheres. We also find that this information does not get clear, either because of its small size or because of its low accuracy.

**Sketch 8:** This idea is based on a normal clock but with the idea of how it could be the union between the shell and the polymer belt. It contains 3 crowns distributed in the right part, although in the interior only a traditional clock is reflected.

**Sketch 9:** Design proposal on which the final proposals will be based. It is a traditional watch with nautical theme. The design proposal is to replace the typical marks that show the hour, by a rope around the carcass with a series of knots distributed so that each knot would equal the mark of one hour.

In this sketch, in addition, it begins to outline how could be the logo of the clock.

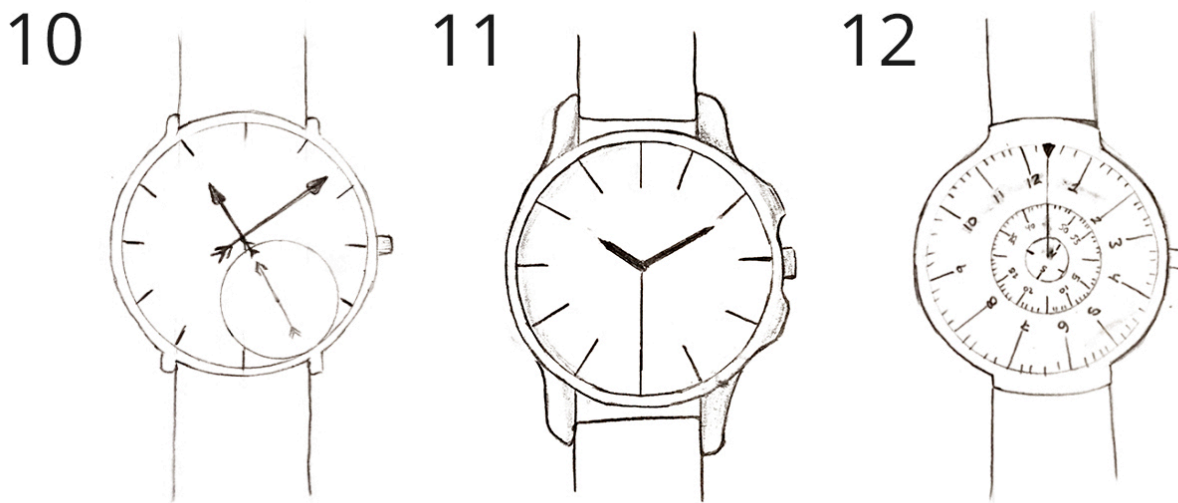


Figure. 10 Sketch 10, 11 & 12

**Sketch 10:** Continuing with the distribution of spheres, we find a very simple clock, which contains two spheres, one smaller in the lower right. The larger dial would mark the hour, while with a click of the crown, would become a chronometer.

On the other hand, the smaller sphere would be equivalent to a compass.

This proposal seeks the method of teaching the information of the compass within a sphere embedded in the large sphere, so that it is not so small as in other solutions, due to the importance we give.

**Sketch 11:** This sketch adds the idea of the shape that could have the casing and its hook with the strap. Remark how the crown ends up being protected with the casing so that it does not involve a nuisance with the user when touching with the hand.

It is a proposal that seeks to give the sensation of rigidity and solidity, improving the previous proposals.

**Sketch 12:** Proposal that is based on the rotation of spheres and not on the use of hands as a method of obtaining information. In this case it consists of 3 spheres where the inner sphere is the compass, in the median a stopwatch and on the outside a watch.

It is a proposal that perhaps makes the way of seeing information somewhat difficult, and it would be a learning investment for the user to have to get used to a method like this.

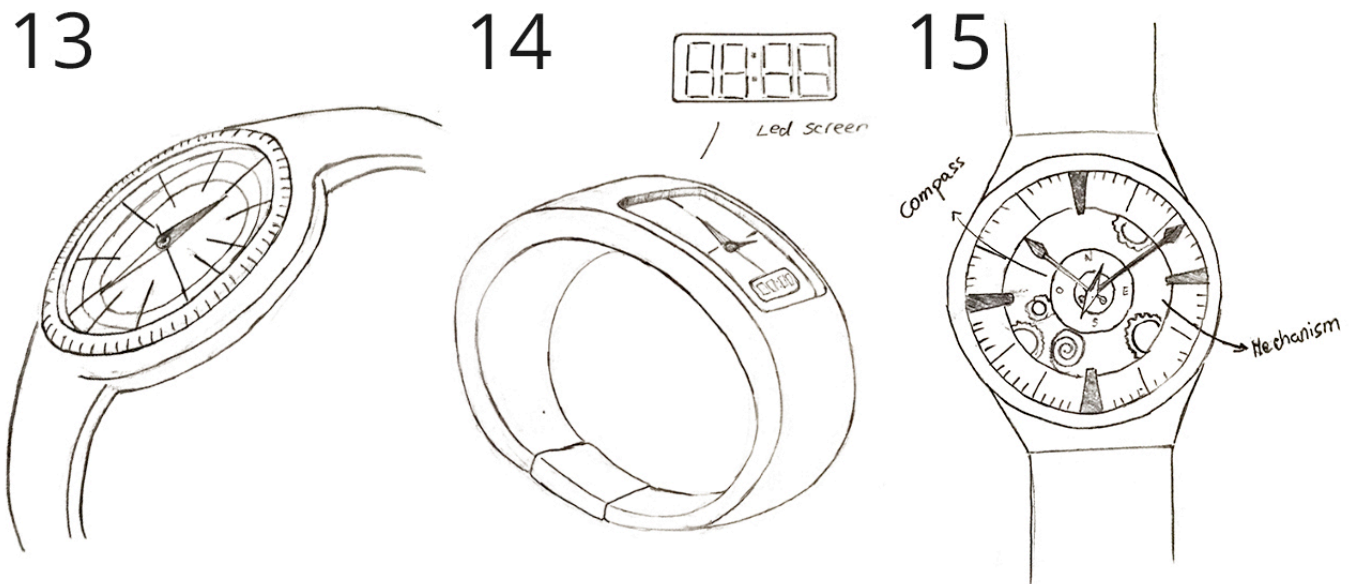


Figure. 11 Sketch 13, 14 and 15

**Sketch 13:** This sketch is based on the shape of a compass adapted to the hand. Although the sphere is not circular in shape but cylindrical, within it would be only two hands, one white and one black. With them it would be intended to teach all the information, so that when changing between modes, one hand would indicate the hour (the black) and the other the minute (the white). In its compass function, the black hand would point to the north and the white to the south, as you can see in the drawing. This sketch also serves to integrate the concept of a compass-shaped housing, which will be further worked on in more depth.

**Sketch 14:** Idea based on the solutions of quantifying bracelets that are at present. This is due to its good integration with the plastic straps, which allow to be more aimed at sports environments. The carcass would have a rectangular shape and would integrate a small screen where you could see with more precision, either the coordinates or the time.

**Sketch 15:** An idea of integrating spheres into spheres. In this case we would have only 2, a small sphere in it that would show the compass, and another bigger sphere that would show the hour.

As a design we introduce the concept of being able to see the mechanism inside the watch.

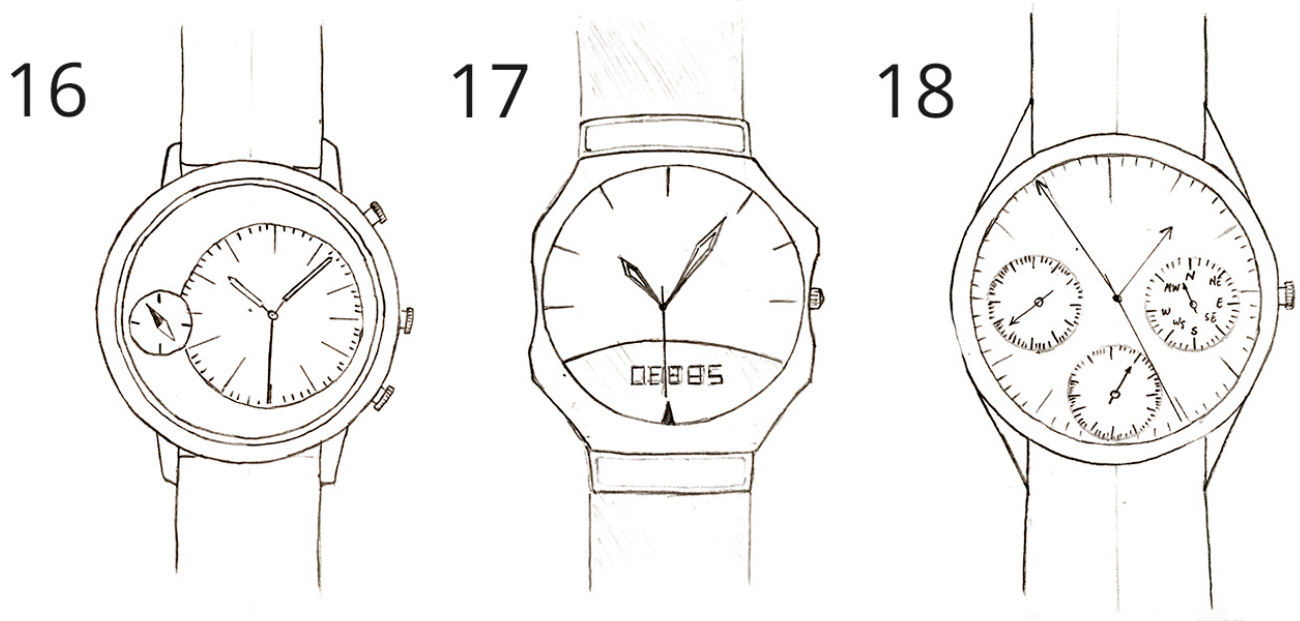


Figure. 12 Sketch 16, 17 & 18

**Sketch 16:** Proposal that expresses that it is not necessary to occupy all the space that provides the carcass, and that plays with the idea of supplanting one sphere on top of the other. In this case a normal clock and to its left a sphere that shows the compass.

Like crowns we have 3 crowns distributed to his right that would fill functions of this watch, like for example the use of a stopwatch employing the sphere of the hours.

**Sketch 17:** Housing with a different shape, which also protects the crown as in an earlier proposal. In this case the proposal is to include an LCD screen at the bottom of the dial, so that all additional functions are used from there to a traditional clock. Due to this screen, a small arrow has been included that marks the 6, so as not to leave the uncertainty of the position of the needles.

**Sketch 18:** More advanced concept to the past proposal of spheres inside the casing. He still remembers the atmosphere of the control panel of an airplane, although in this case the space is better taken advantage of because the outer sphere has the utility to mark the hour.

In this case we find two stopwatches. One of them intended to make the countdown of the 5 min that has been mentioned so much in the interviews.

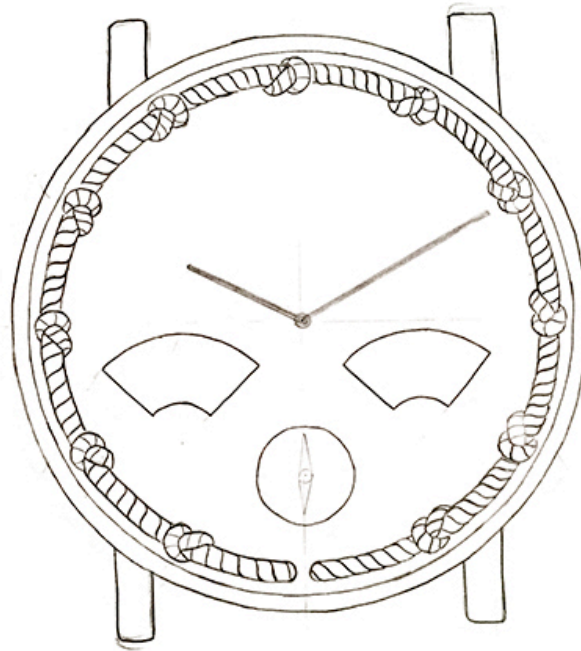
The housing also gives a robust appearance to the housing.



## 5.2 Final Proposals

Within the process of drawing ideas, three proposals came up that will be analysed below, explaining which points are the most favourable and those that are not, for the final design. Many ideas are common, although they differ in different things. The final proposals:

### 5.2.1 Sketch A



*Figure. 13 Proposal A*

The first final proposal is based on sketch 9 of the previous section. It consists of applying the idea of strings that replace the marks of the hours adding the functionalities that were missing to the initial sketch. In this way we have 3 spheres in the interior, which the upper two would rotate to vary the drawing shown, and in this way change the type of information that shows the user.

The initial idea contemplated using one of these rotating spheres to show the time it will do in a time range established by the user through an app. This idea was discarded because it is not so important to know the time during a race, since the function is not to save on the work prior to a competition, but to improve the experience inside the race.

The central sphere contains the compass, although it was concluded that it was too small to be precise enough for a competition of these characteristics.

Finally the design of the classic body did not give enough rigidity to think of a competition environment, so they were also one of the points that discarded the idea.

### 5.2.2 Sketch B

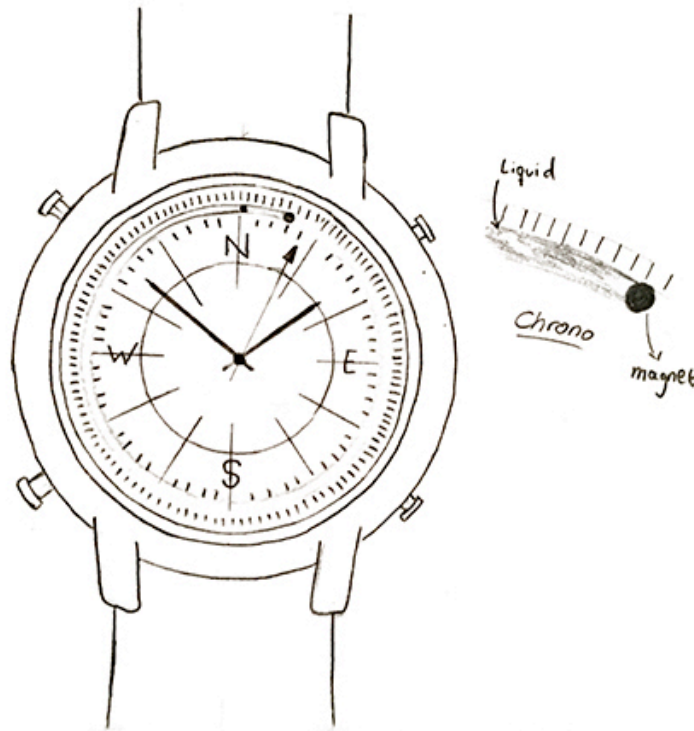


Figure. 14 Proposal B

The following proposal is based on the interior design of a compass, providing the highest possible accuracy when teaching information. There are two different scales that give the product more precision.

The first is the outer one, which divides the whole sphere in seconds and is marked by a complex system that uses a magnet and a ball to rotate and let the liquid flow through the interior of the conduit. In this way, when the user wants to consult the elapsed time, the magnet will have travelled a certain distance, allowing the adequate liquid to pass to fill the sphere.

This system of liquid to show a measure was discarded by its complexity, but it is an idea that was taken seriously in consideration.

The second scale has a double function, it serves as a scale to know the position of the cardinal points as to mark the time, as it is divided into 12 parts and in turn, in the 60 that would mark the minutes.

In this sketch, in addition, the idea was introduced to use the needles of the clock so as to mark the hour as to indicate the north, so that the space to show this information would be highly utilized.

### 5.2.3 Sketch C

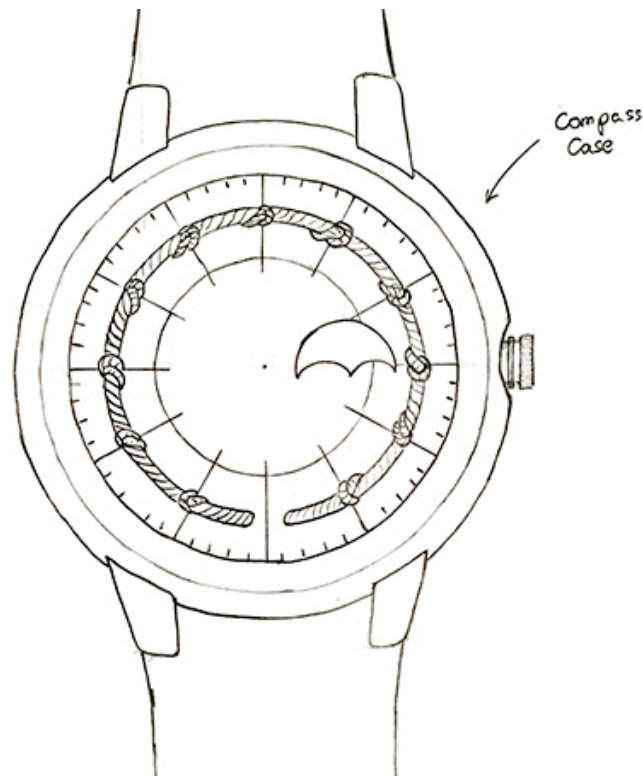


Figure. 15 Proposal C

Finally, the third sketch tries to combine all the best elements that have emerged in the last brainstorming.

The problem of a body with a fragile appearance was solved by imitating the body of a classic compass. This sphere achieves sufficient grip on the belt and sufficient stiffness for an exhaustive use.

It includes the idea of the rope as a time stamp, but in this case the scale would be much more accurate when counting in its interior with a drawing of a scale to mark both the hours and the position of the north.

In addition, there is also the idea of using the needles both to mark the north, to mark the time or to be used as a stopwatch.

It has a sphere on the right side that with the rotation will mark in which way the watch is.

Finally, we find a crown protected enough not to disturb the user during use. It also allows you to have a bigger size and improve your ergonomics when interacting with it.



## 5.2.4 Final proposal



*Figure. 16 Final proposal*

Finally, the proposal chosen for its further development is proposal C. This proposal meets the requirements set forth above, as well as being the most solid solution to the problems raised.

One of the strengths, moreover, is the ability to display information very clearly compared to other proposals. Thanks to its rotating mode dial operation, it allows the needles to change their function according to the desired mode.

This takes full advantage of the whole watch and is not reduced to only a small part of it. This achieves greater accuracy by being able to see the marked data more accurately.

From this design, in the following sections will be studied which should be the appropriate measures of each component, in order to ensure the highest possible ergonomics. In addition to detailing both its operation and the materials that compose it.

### 5.3 Anthropometric study.

The anthropometric study consists of the study of the dimensions of the human body. Covering all possible measures and ages, you can find a range where more users appear, what is known as gauss bell. The data collected in this section will be used later in the ergonomic study and finally in the dimensioning of the final proposal.

In this way, the objective of this study is to think and design a product with the intention of covering as many users as possible. Important also, because this study key to accessible design.

For an adequate anthropometric study, the percentile or collective to which we focus our work should be defined. For this project we will focus on a single percentile, since choosing the ranges of the ends P5 and P95 would not be valid as it is not limited to optimal functionality.

The chosen percentile is the range that is made up of P25 / P75. With this it is possible to encompass most of the studied sample

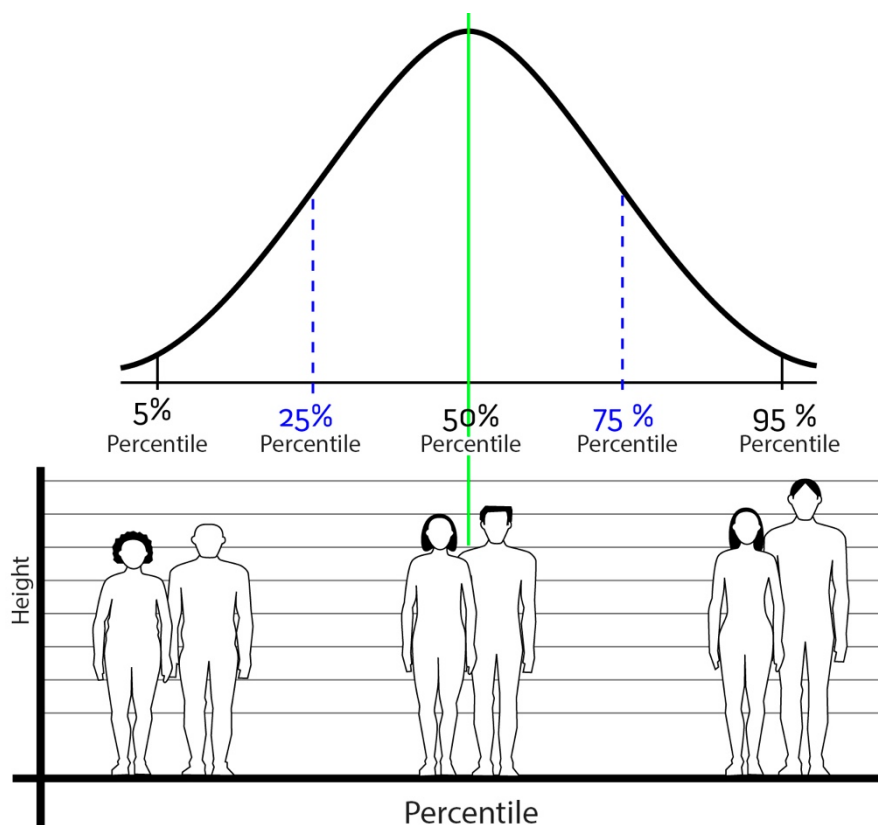


Figure. 17 Percentiles of men and women type P25/P75

Once the percentiles are established, the next step is to decide which major types of measures to study. In our case the project is about the design and creation of a clock, so [acabar esta frase]:

- **General Anthropometric Measures:** Measures necessary to dimension our product. With special emphasis on the longitude of the arms in order to study the movement that the user has to do to consult the information provided by the watch.
- **Anthropometric measurements visual field:** Necessary to know the range that has the visual field of the user in order to place the information correctly in a correct position.
- **Anthropometric hands:** Necessary to know the measures of the elements that interact with the user, such as the size of the hands
- **Anthropometric Wrist Measurements:** Measures necessary both to know the proper size of the watch strap, and to the size of the dial in order not to disturb the movements of the user.

The information in the following tables has been taken from **DIN 33402**

### 5.3.1 General Anthropometric Measures:

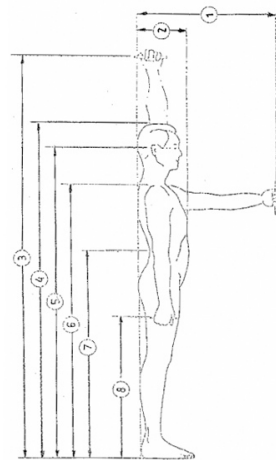


Figure. 18 General Anthropometric Measures

Dimensions in mm (DIN 33402)	Percentile					
	Men			Women		
	25%	50%	75%	25%	50%	75%
1. Maximum extension arm	692	722	754	653	690	726
2. Scope of the arms upwards	1980	2051	2130	1809	1870	1935
5 Eye level	1561	1613	1667	1561	1613	1667
6. Height to hand (closed shaft)	747	767	797	701	738	770

Table. 7 General percentiles by sex

### 5.3.2 Anthropometric measurements visual field

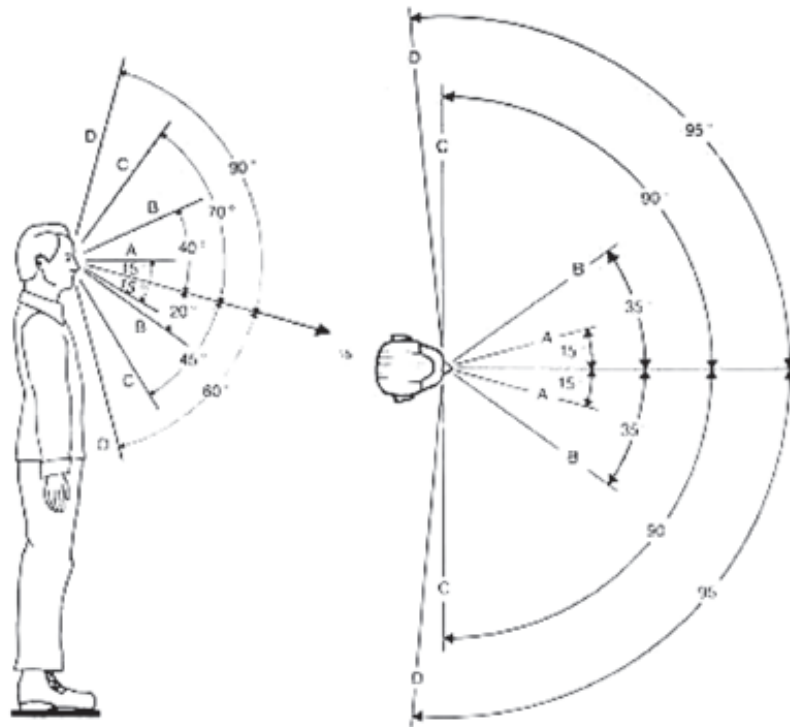


Figure. 19 Anthropometric measurements visual field

Dimensions in degrees ° (DIN 33402)	Vision	
	Ground	Profile
A. Optimum angle	30°	30°
B. Recommended maximum angle	60°	70°
C. Maximum angle of vision	115°	180°
D. Angle limit	150°	190°

Table. 8 Visual Field Angles

### 5.3.3 Hands anthropometric measures

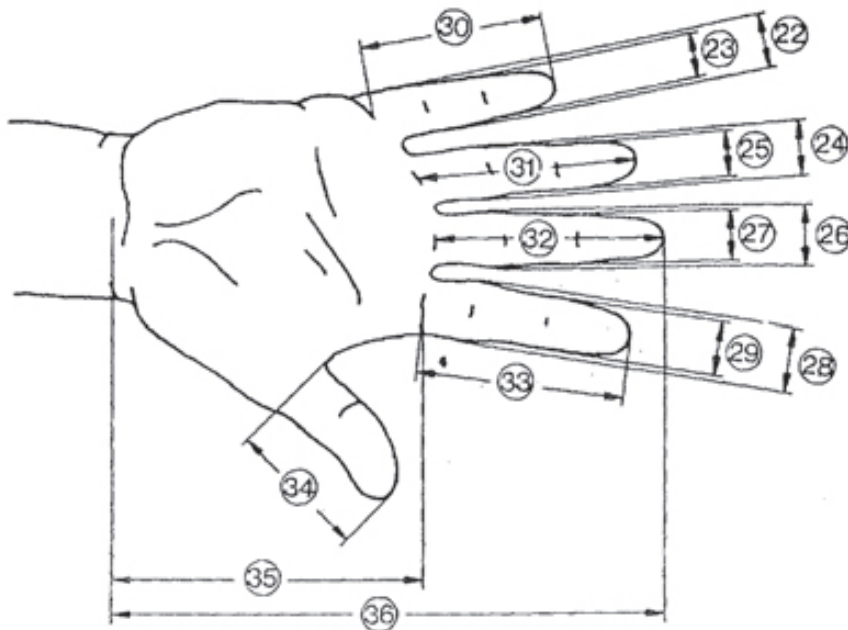


Figure. 20 Measures of the fingers according to sex

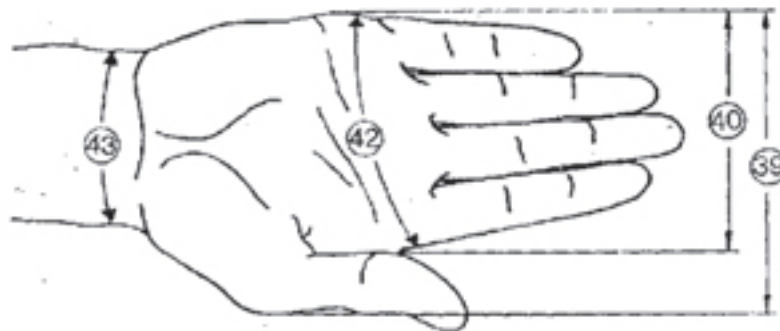


Figure. 21 Measures width of the hand and wrist

Dimensions in cm (DIN 33402)	Percentile					
	Men			Women		
	25%	50%	75%	25%	50%	75%
29. Index finger width close to hand	1,7	1,8	1,9	1,4	1,5	1,6
39 Width of the hand including thumb	10	10,7	11,4	8,4	9,2	9,9
40. Width of the hand excluding the thumb	7,9	8,5	9,1	7,4	8,0	8,4
43. Perimeter of the wrist joint	16,4	17,6	18,6	14,9	16	17,4

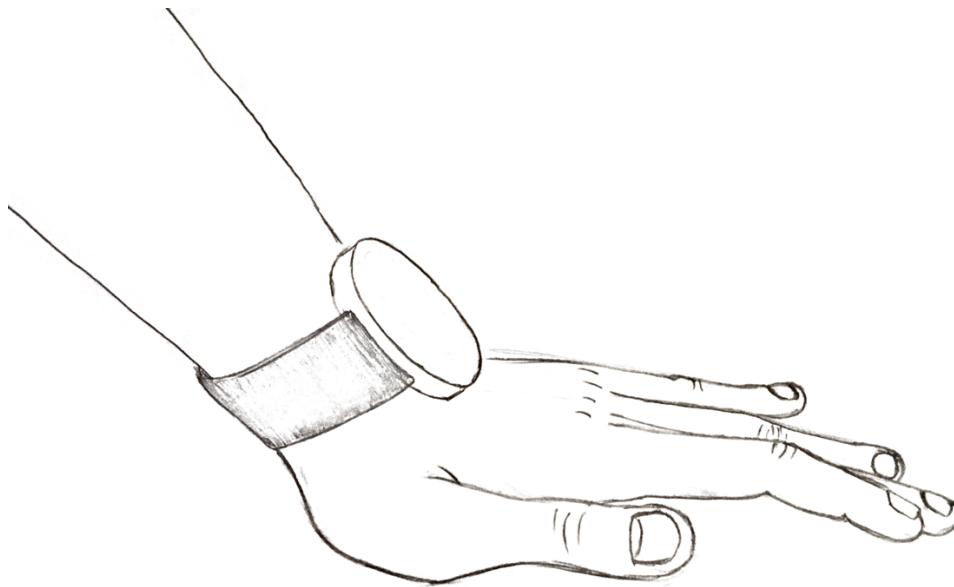
Table. 9 Percentiles of the hand and wrist

## 5.4 Ergonomic study

In this section will study the relationship that the user has with the product, in this case, the clock. In order to find the appropriate measures to encompass as many users as possible with the greatest possible comfort.

Therefore, the data extracted from the previous section are used, the anthropometric study, in this way, the measures used as a reference bring the maximum possible to reality

### 5.4.1 Case size



*Figure. 22 An oversized size can disturb the movement of the hand*

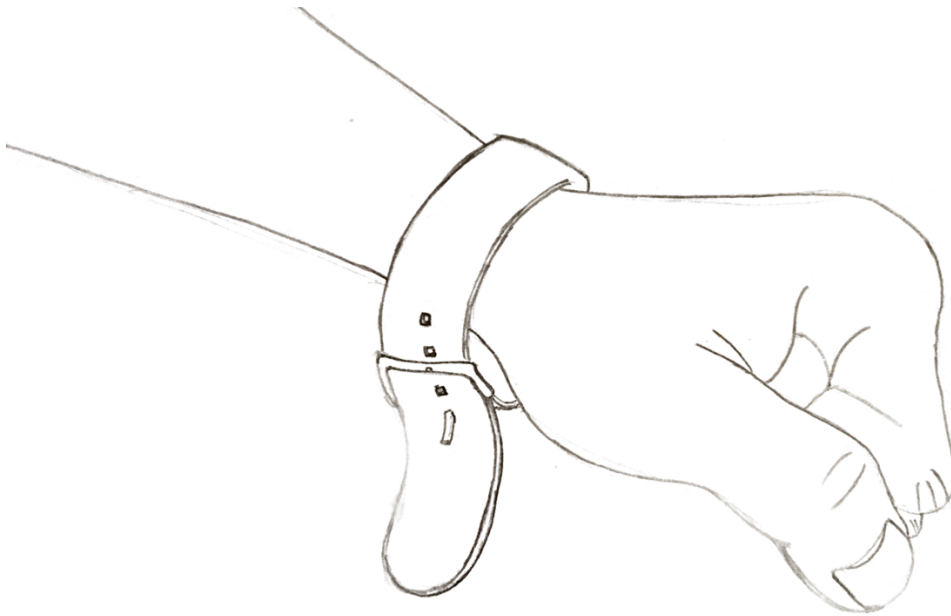
One of the most important measures in the design of a watch is the size of the case.

On the one hand if the size of this is too small, leaves little space for the elements that display the information, and hinders the user interaction with this when encountering too small elements.

On the other hand, a too large housing makes it difficult to move the hand you are in. In this way, it restricts and disturbs the movement of essential tasks that can be performed both in daily life and aboard a boat.

In this way following the tables the optimum measures for the product casing are of a diameter of 38 mm

### 5.4.2 Watchband size



*Figure. 23 An oversized size may not hold the watch well to the wrist*

Another important element is the size of the watch strap, which should allow you to fit the user's wrist in the most comfortable way possible. This is achieved with a width that is wide enough to give some resistance to the belt, but without disturbing the movement of the wrist.

In addition, its length must be adequate to the diameter of the wrist, since if it is too long, the leftover belt may disturb. Similarly, if the belt is too short it would not be possible to close it, or it would tighten a lot. That is why finding the right length for the wrist is a key factor.

For the length of the strap we will use the previous tables in which the diameter of the average wrist in the masculine gender oscillates between 164 mm and 186 mm.

### 5.4.3 Crown Size

The watch contains a strap with which the user interacts, allowing both the change between modes and the change within their functions. This should be a suitable size for comfortable handling with thumb and forefinger.

If the crown is too large it can be nailed to the user's hand, and on the other hand, if the crown is too small, it can be difficult to handle when you want to interact with it.

In this way the measures used for the ergonomic study of the crown have been the measures of the index [Table 4, measure 29]

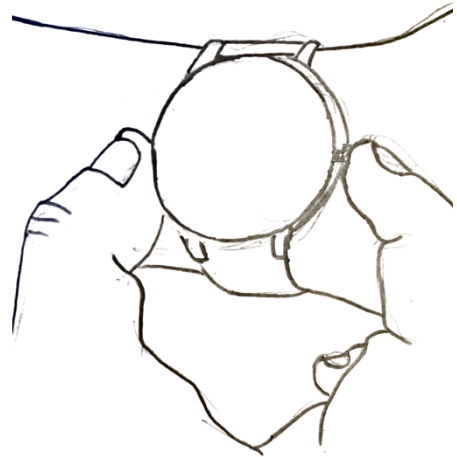
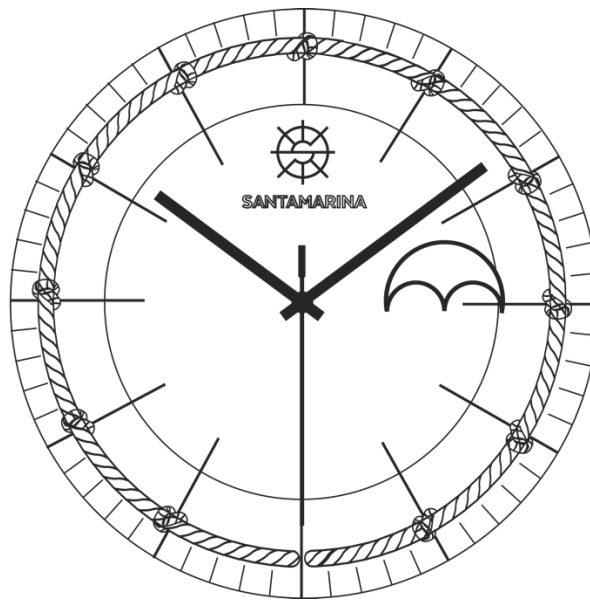


Figure. 24 Interaction with the Crown



#### 5.4.4 Distribution of the elements



*Figure. 25 Distribution of the elements*

Finally, the size and arrangement of the elements on the watch are crucial factors for a comfortable use of the product. In this case the study that has been carried out is the distance from the wrist to the head at the time of consulting the clock. This parameter varies according to the length of the user's arm, so the anthropometric tables have been used to estimate the distance to which the user reads the information on the watch.

These measures range from 35 cm to 45 cm, so this will be the base to be used so that the information can be read at this distance in a housing of 38 mm

## 5.5 Dimensional proposal



Figure. 26 Proportion of elements

After a thorough study of the appropriate dimensions that the watch must have to have the best possible interaction with the user, a series of measures have been established. These will be divided into two parts, on the one hand measures related to the housing where it will contain the mechanism and the needles that will mark the information. On the other hand, the watchstrap, which due to the great difference of sizes that we have found in the anthropometric study, it has been decided to employ a series of sizes according to their size.

### Measures of the Case

As mentioned in the previous section, the measure of the diameter of the casing for this watch will be 38 mm, a measure that allows a comfortable use during the movement of the hand.

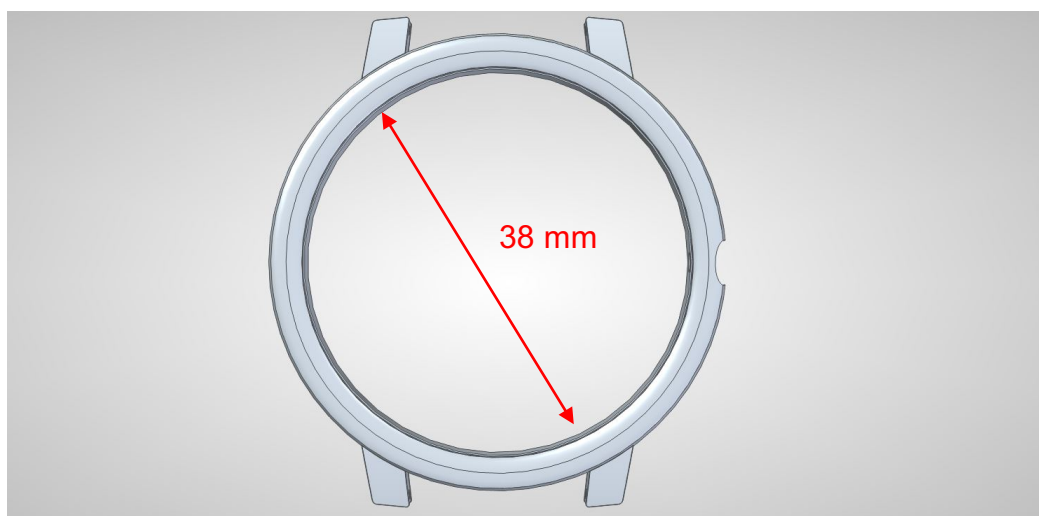


Figure. 27 Diameter case

For the thickness of the case, the measure is 12 mm.

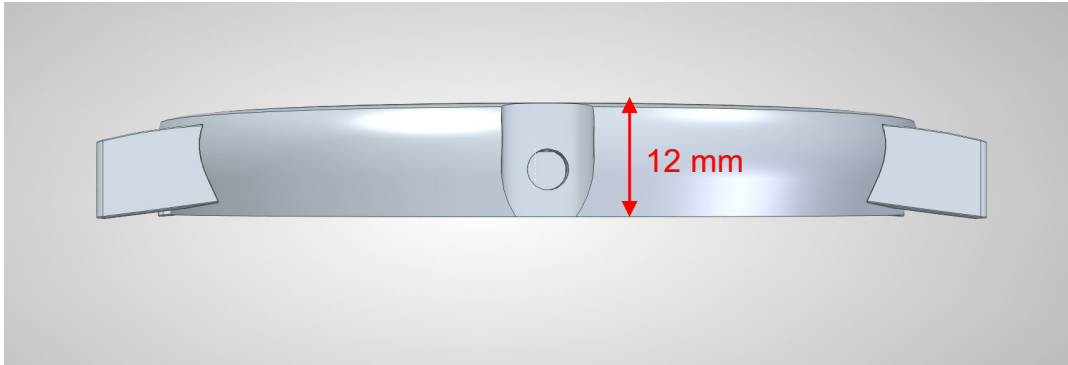


Figure. 28 thickness case

### Measures of the Watchstrap

Following the ergonomic study carried out in the previous section, it has been decided that the belt size will have a width of 20 mm, allowing comfort in its use in addition to being wide enough to have the desired strength.

The long of the strap will make 220 mm, a sufficient width to cover a percentile of quite important users, and not to spare users with small wrists.

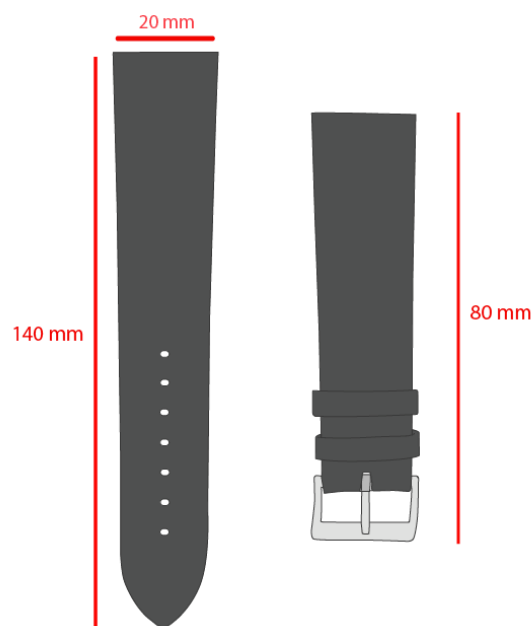


Figure. 29 measures watchbstrap

## Measures of the Crown

The crown will have a diameter of 3,4 mm, and 3 mm of width. Measures that

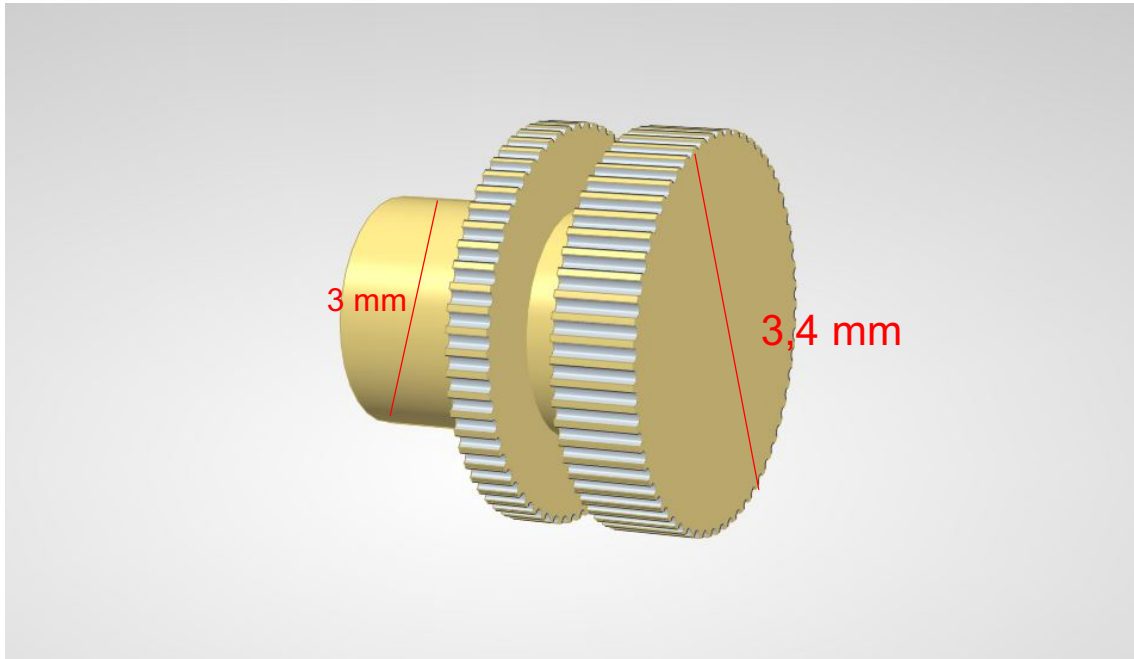


Figure. 30 Measures crown

## 5.6 Functional and usability study

In this section will detail the functions of our watch. For this we have based on many factors, such as the interviews conducted, the analysis of the problem, or the previous briefing imposed to find the best solution. All this in order to provide a useful and effective product for the type of user to which it is directed.

### 5.6.1 Watch

The main function of the product is to mark the time to the user in a comfortable way, so there are 3 different needles that will each mark a time element.

- Long marking needle
- The short hour marking needle
- Thin needle marking seconds

To make a change of time the user must hold the crown of the watch for two seconds and can rotate the crown to move the needles at the corresponding time

### 5.6.2 Compass

Through a determined pulse in the crown, the clock changes its function of marking the hour to align its needles marking the north at all times. In this way the user goes from having a conventional clock to an element necessary for navigation.

One of the most needed features within the compass function was the idea of being able to keep positions on the compass, since it allowed them to know the degrees that had rotated the boat at all times. With this system it is possible to use the hour hand to set positions, for this, in this mode, the user must hold the crown and the needle will remain still.

If the user would like to reset these functions, he would only have to change his function with the appropriate keystrokes

### 5.6.3 Chronometer

Another feature of the device is the timing function, in which the internal clock will calculate the time elapsed with accuracy of seconds. When the user changes to this function, the three needles will be set to 0, that is, dialling 12. When the user presses it, the stopwatch will be activated and the second and minute hands will advance at the same speed of the seconds. When 1 minute passes, the hour hand moves at minute 5, so that you can clearly see the minutes and seconds that have elapsed.

This is in this way since it is often difficult to see quickly the exact minute the clock ticks.

#### 5.6.4 Function of the crown and sphere modes

The device will have a single crown from which all the commands of the watch can be accessed. This function should be as simple and intuitive for the user. So that you do not have to memorize its use and that simply with the intuition its functions can be used.

In this way, through the crown will allow the change of functions between the different modes, for this the user should only perform the appropriate keystrokes to change, following the following pattern:

- **2 keystrokes:** The dial indicating the current mode changes to the next mode
- **3 keystrokes:** The dial indicating the current mode changes to the previous mode
- **1 keystroke:** Activates a primary function according to the mode in which the device is:
  - **Compass:** a position on the clock as previously explained
  - **Stopwatch:** Pause / resume the stopwatch.
- **Press and hold:**
  - **Clock function:** Activates the time change mode, which allows the user to rotate the crown to move the hands until the clock is set. A single press will re-activate it
  - **Compass:** If you have a fixed position, with this key press the north again with the minute hand
  - **Stopwatch:** Resets the time set by the watch

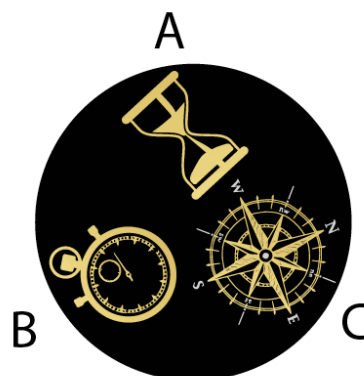


Figure. 31 A. Timer Function - B. Chronograph Function - C. Compass Function

## 5.7 Moadboard

For the creation of the visual universe of the project the creative tool Moadboard was used, which consists of a collection of elements that serve as inspiration for visualizing a style. In this project emerged diverse elements like the Mediterranean style, the luxurious style or the Mediterranean style.



Figure. 32 Moadboard



## 5.8 Colour and Trim

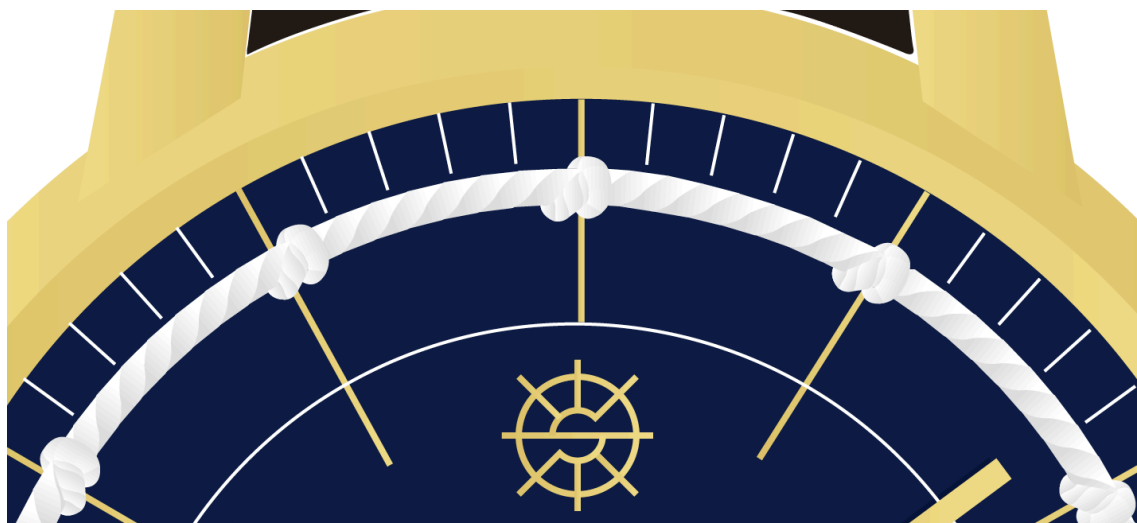
When you consider the visual aspect of a product, the colours of this are a very important part of its development. These need to be in harmony and transmit the same as it transmits the product itself.

From the beginning the idea of sailing sports was present, as well as colours that remind the Mediterranean Sea and the navigation itself. That is why the dark blue tones and white should be present as main colours.



*Figure. 33 Typical Mediterranean buildings*

For the watch dial, the background colour chosen has been dark blue, with white details such as the string around it or the marks of the divisions that indicate the minutes.



*Figure. 34 Detail os the colour of the marks*



As a complementary colour, gold was chosen, an analogous colour in the colour wheel with respect to the dark blue, which combines perfectly for details and aesthetics in general. The case that will contain the watch will be this colour, as well as the marks that represent the hours, or the hands of the watch.

For the leash the chosen colour is a black because it is a neutral colour that combines with any colour besides being of a plastic material. As a variation one could use the same dark blue present in the casing, which would give some continuity to the product.

Although these colours represent a very definite proposal, the intention is to bring to the market a product with different ranges of colours, in which each range will be accompanied by a new set of straps. In this way it is intended to draw colours models focused both for the female audience as well as a distinction in different sizes that seeks to fit more to the type of wrist and style of each user.

## 5.9 Selection of materials

In this section will be a study of materials to find the most suitable materials with certain characteristics, these characteristics depend on the function they exercise, such as its mechanical strength, or its toughness; as well as other parameters defined by us, such as price or recyclability.

To carry out this study, we will first define which parts are to be analysed, since there are components in which there is little choice or their choice does not affect the final proposal of the product, such as needle material, or the type of rope that is used, since it exerts only an aesthetic function. In addition, there are mechanical components and electrical components of which we do not have the control, since they are usually defined by the manufacturers of these.

The methodology of this study is simple, we start with all families of materials at once. And these are being reduced according to the selection criteria that we are adding.

For this it will depend on which piece we are looking for. For this study has been used the program CES Edupack version 2013, which has a large library of materials and allows us to follow a graphic procedure for their selection.

In order of priority we are interested in:

1. Strap
2. Housing
3. Crystal
4. Needles, bottom, inner mechanism and rope

### The Importance of Allergies and Nickel

In recent years, the number of allergy cases by materials such as nickel, have triggered alarms in dermatologists. Many manufacturers use solutions with a significant content of this element that causes allergic reactions to those who use it when mixed with the sweat of the user. These marks also do not inform at any time of the elements contained in both the casings of their watches and their straps.

When choosing the most suitable material for our product, this should be a very important element to take into account, as it causes a bad experience for the user and generates rejection towards our brand.

If we provide a product allergy free to the user, we are adding an added value to our product, providing an allergen free product, key value to differentiate us from the competition in a market as competitive as wristwatches.

### **The importance of recyclable materials and their sustainability**

One of the most important aspects when determining the use of one material or another is the recyclability of this material. Disposing of recyclable materials in our products generates less impact on the environment due to the energy saving that is produced both in waste and in the production of a new product with recycled material. There are a number of decisions to be made when considering the life cycle of a product that define the impact we will generate in the environment, and one of them is the use of materials that can be recycled afterwards.

### **The importance of constant contact with salt water**

The initial idea that converge both a watch meant for sailing sports, and traditional watches, makes the quality of some materials should be sacrificed substantially. This is because water resistant materials will be chosen above the rest. In the case of housings there is not much problem as most solutions are metals and have specific alloys that make them resistant. But very common materials for both fabric and leather straps wear out a lot with saltwater contact.

#### **5.9.1 Selection of material for the belt**

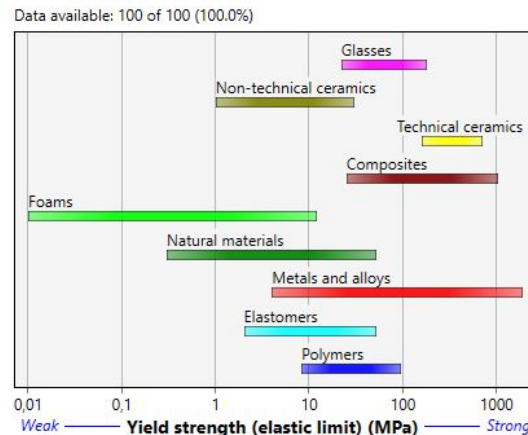
Following the order of priority for material selection, the first component to perform the study is the watch strap. For this we will divide the parameters that we are going to define according to its group, these groups will be the following:

- General properties
- Mechanical properties
- Thermal properties
- Electrical properties
- Eco properties

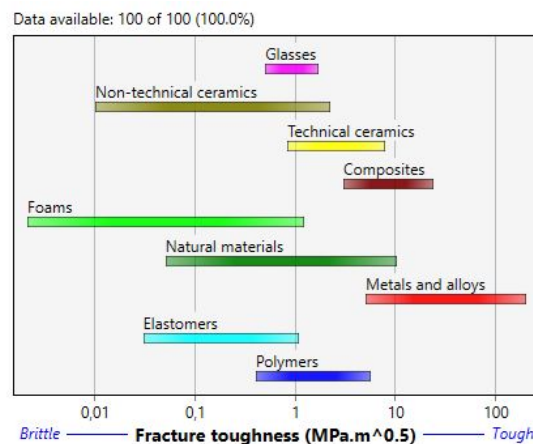
## Mechanical properties:

The first parameters that we will define will be the mechanical properties, a key section in the selection of materials since it will allow us to choose within the most adequate family. In this range we find the following properties:

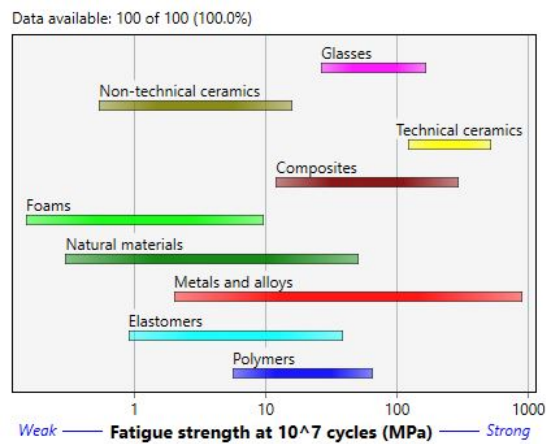
- **Elastic limit:** High, to avoid deformations in minor impacts. [ $> 10$  MPa]



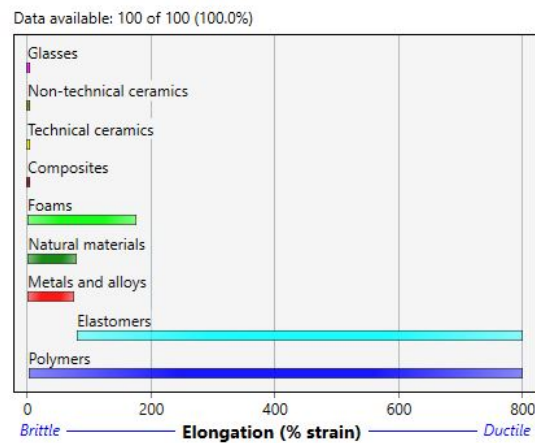
- **Tenacity:** High, we are interested in that the belt can undergo elastic deformations without suffering a permanent deformation [ $> 0,5 \text{ MPa} \cdot \text{m}^{1/2}$ ]



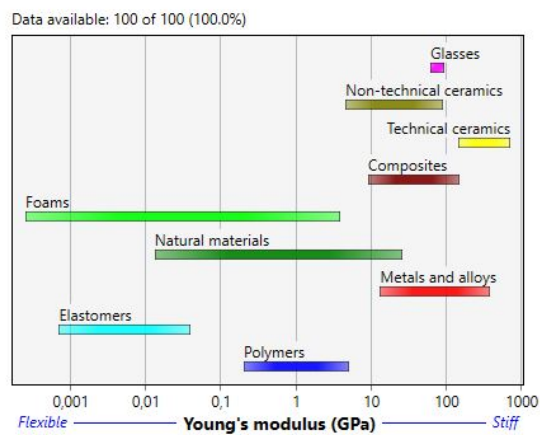
- **Fatigue:** High, due to its use, the component will be subjected to many dynamic loads cyclical over time, so you have to have a good resistance to this. [ $>12$  MPa]



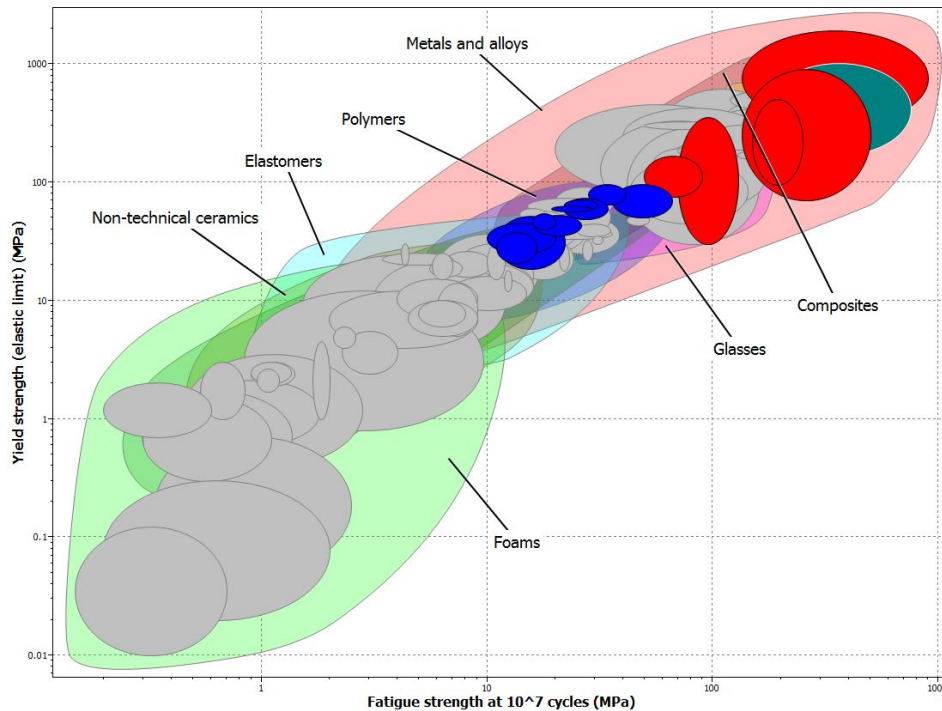
- **Elongation:** High, to fit the user's wrist [ $>50$  % strain]



- **Young's Modulus:** [ $> 1$  GPa]



Once the mentioned parameters are applied, the list of materials that fall within our characteristics is reduced, leaving 65 possible materials with the added data



In the chart above you can see how both foams and ceramic materials were discarded in our first selection.

### General properties and thermal properties:

The next step is to add to the selection filters general properties, of which we can find the following:

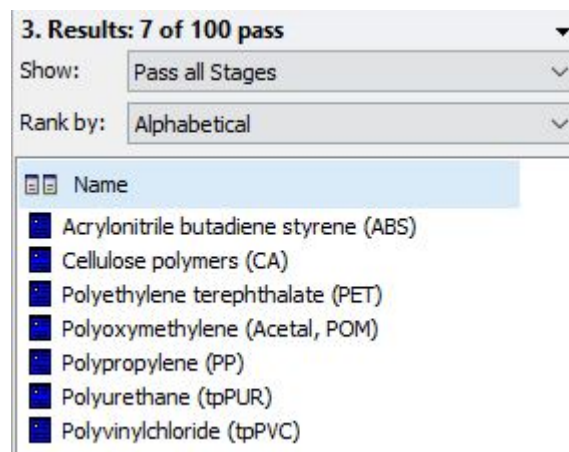
- **Density:** Normal, if the belt weighs too much can annoy the user, and if it is too light it can give the impression of being of low quality. [ $600 - 3 \cdot 10^3$  kg/m<sup>3</sup>]
- **Resistance to solar radiation:** Very high, it should be designed to spend a lot of time under large doses of solar radiation.
- **Resistance to temperature variability.** High, must be able to accompany the user in the most extreme conditions, from very cold to extremely hot environments. Minimum service temperature [ $< -75^\circ\text{C}$ ]
- **Maximum service temperature** [ $> 100^\circ\text{C}$ ]
- **Good thermal insulation:** High, good thermal conductivity can cause the belt to be very cold or very hot for a long time in contact with the user. [ $> 0,1$  W/m  $^\circ\text{C}$ ]

## Eco properties:

Finally, within the options that remain, we will check if the solutions found, which can be discarded for not being recyclable.

- **Recyclable:** Yes, because we want to be able to produce a sustainable and ecological product. For this, the use of products that can be recycled is key in their selection. [Full or half-full]

Once the filters are applied, the only family of materials left are the polymers. Specifically, these 7:



The next step is a study of water resistance of these polymers, since they are going to be the conditions that will demand the environment to which they are destined. For this the parameters that we will use will be the following:

**Fresh water:** Fresh water is ubiquitous: any object: exposure to rain, to washing or to high humidity acquires a film of water containing (unless distilled) dissolved oxygen and, usually, other impurities [>Excellent]

**Salt water:** Marine environments, both as water and as wind-carried spray. Seawater varies in composition depending on the climate. Body fluids have about the same salinity as the sea. [> Acceptable]

Once all the variables have been added, two results appear: Cellulose polymers and Polyurethane. Because the second option has greater resistance to the day-to-day environment, it will be the material we are going to choose.

3. Results: 2 of 100 pass	
Show:	Pass all Stages
Rank by:	Stage 1: Water (fresh)
Name	Water (fresh)
Cellulose polymers (CA)	Acceptable
Polyurethane (tpPUR)	Excellent

### 5.9.2 Material selected for the watchstrap

In this way the watch strap will be Polyurethane, one of the most flexible materials within the family of polymers, since depending on the mixtures that are made can be very elastic or very rigid. In this way we can play with your composition to achieve an ideal element for the comfort of the user, fulfilling the minimum requirements that we have demanded in your selection process.



In addition, it is a plastic that can become recyclable depending on the treatment you are given. That is, it may be thermoset or a thermoplastic depending on its composition.

For the watch strap it will be used in its thermoplastic version, because it allows us to recycle the material at the end of its life cycle because, when heated, it does not degrade and can be re-melted for use with another function (such as tires) . That is why it has the number 7 within the classification of plastics, as it enters the family of recyclable thermoplastics.

### 5.9.3 Selection of material for the case

The next element we will define is the material of the watch case. For the selection of the material of the case different factors are taken into account beyond the mechanical properties of the material. Such as density, price or water resistance.

For the selection of materials of the case the following parameters have been used:

#### General Properties:

- Density:  $< 9 \cdot 10^3 \text{ kg/m}^3$
- Recyclable: Yes

#### Mechanical properties:

- Young's Module:  $> 100 \text{ GPa}$
- Elastic limit:  $> 150 \text{ MPa}$
- Hardness (Vickers):  $> 300 \text{ HV}$

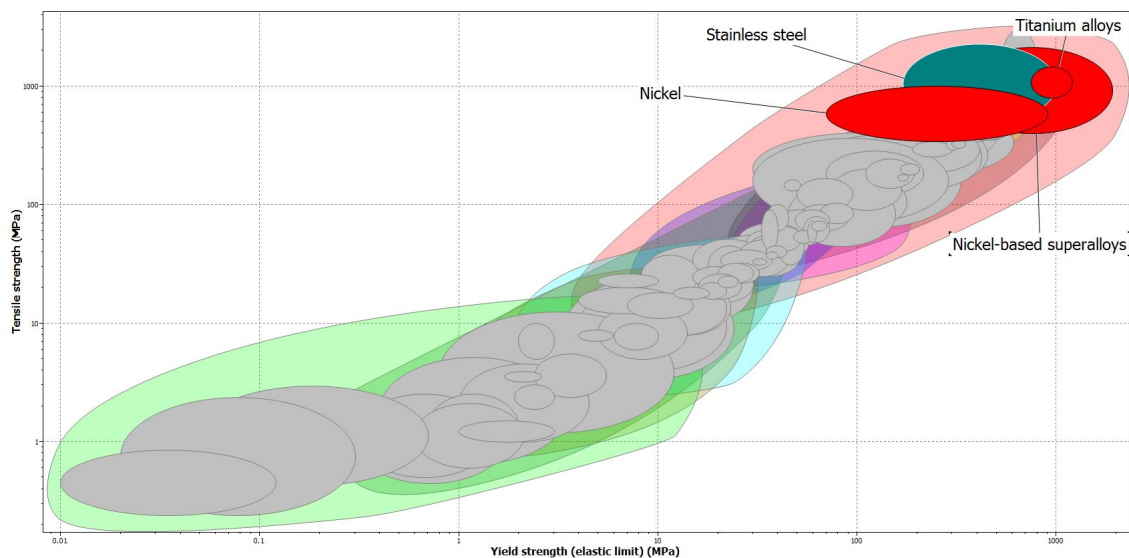


- Fatigue strength:  $> 150 \text{ MPa}$
- Fracture roughness:  $> 50 \text{ MPa} \cdot \text{m}^{0.5}$

### Water Resistance:

- Fresh water: Excellent
- Salt water: Acceptable

Once defined these parameters we leave 4 possible solutions as material for our casing:



To make a final discard, we will order the 4 elements according to their price. From major to minor, this way we will verify the difference that exists between materials with very similar characteristics for the function that we will give.

3. Results: 4 of 100 pass	
Show:	Pass all Stages
Rank by:	Stage 1: Price (EUR/kg)
Name	Price (EUR/kg)
Titanium alloys	19.9 - 21.9
Nickel-based superalloys	19.4 - 21.3
Nickel	14.5 - 15.9
Stainless steel	4.59 - 5.06

Making an analysis of the price of fabricating with materials such as titanium or nickel super alloys, are discarded from the list because of its high price. With titanium could be achieved a product of extreme lightness with very good properties, but with a price too high.

For this reason, the material chosen for the product casing is stainless steel due to its great mechanical properties and its high resistance to contact with water.

#### 5.9.4 Material selected for the case

Within the family of stainless steels, we find different families according to the percentage of their alloys. In this way the families that make up the steels are the following:

- Ferritic stainless steel
- Martensitic stainless steel
- Austenitic stainless steel
- Stainless steel Duplex (austenitic-ferritic)

This selection is based on the percentage of chromium and nickel present in the alloy.

Because the treaty we want to make to the material is going to be a stepping process, improving its resistance to scratches and bruises, the steel to be used will be the austenitic.

Austenitic steel is also characterized by having a percentage of more than 7% of nickel, a chromium content between 16 and 28% and of 1.5 to 6% in molybdenum, a material that improves the chemical resistance of the alloy.

According to dermatological studies, the presence of nickel in these steels does not present a danger to the allergies suffered in the skin, because it is a very small percentage and this falls within the regulations associated with nickel in metal objects. (See normative section)

Commercially, the different alloys of steel are known with a nomenclature divided into series. In the case of austenitic steel its series is number 300, that is, within the variety of steel families, all those with a nomenclature with the number 300 would be of the austenitic family.

But within each alloy the percentage varies giving rise to some properties or others, although they remain within the austenitic family.

For the watch, the series used is the **Stainless steel 316 Series**, because it is a corrosion resistant alloy against various aggressive chemicals, acids and above all saline atmosphere. It is usually used for architectural decorations, food processing, pharmaceutical, etc.

This resistance is given the percentage of Molybdenum present in the chemical composition.

### 5.9.5 Selection of materials of the rest of components

#### **Needles and decorative internal elements:** Anodized Brass

Due to its lightness and the ease with which it can be made pieces of so small size and precise by means like the stamping, the brass is one of the best options for the needles of the clock. Thanks to the different anodizing techniques allows us to choose an ideal colour for our product, besides protecting against external agents and protect it from oxidation

#### **Crystal:** Sapphire crystal

For the selection of the glass of our watch we searched for a glass very resistant to impacts and scratches produced by the daily use of the product. That is why the most appropriate option is a crystal sapphire alloy, which provides mechanical characteristics ideal for the function that has to exercise.

#### **Rope:** Polyester fibre

For the rope material inside the watch dial, the actual material of a mooring rope has been sought. At the present time this material is no longer of natural fabric and the solutions that are used at present are of polyester fibre

## **6. Brand image proposal**

With the development of the watch designed for sailing sports, the need arises to create a brand according to that product. This section will explain how has been the development of the brand image proposal that will accompany the product. Each section will justify each design decision and how it has been reached there.

## 6.1 Name of the brand.

This project is based on a personal project, so the brand will also be linked to the designer. That is why the name of the brand will be *Santamarina*, a name that is in line with the theme of sailing sports and its maritime environment.

With this name for a brand of watches, the user comes to mind a certain aesthetic, with colours and tones that remind you of maritime life. This is what you want to achieve with the image of the brand that will be detailed later.



*Figure. 35 Image of the Name's Brand*

## 6.2 Logo.

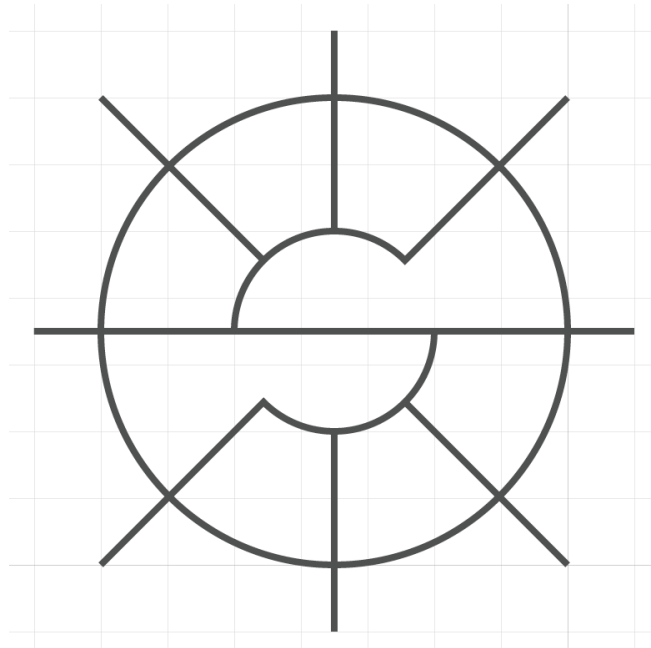


Figure. 36 Proportions in the logo design process

For the logo of the mark, an icon of a rudder has been designed that will accompany the logo. This icon will be an emblem that will appear both in the various official documents of the brand and in the details of the products of the mark, as for example in the main crown or in the second hand.

The choice of a rudder would be the image that would represent the company that will accompany the product, comes from the importance of the first steps for a company. Know where to go at all times so that you never lose your way. This is the philosophy that is intended to give.

Another symbol that would represent the company is the initial S, and in this icon was wanted to appear to reflect that belongs to the brand. For this it has been achieved eliminating the lines of the interior of the icon, leaving between seeing a silhouette in the form of S.

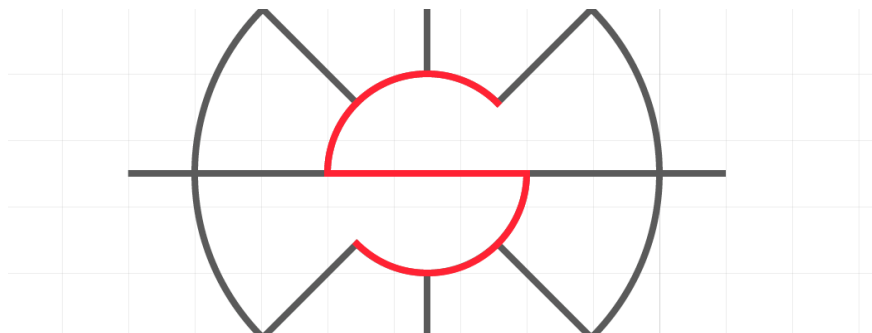


Figure. 37 S shape inside the logo

The next step in the design of this logo was to integrate it into a shield-shaped frame, which would represent the strength of the company. This framework that accompanies the logo has a double function:

- Protect the logo when it is located in different areas, you can see an example of how this logotype would be in official documentation in the following sections.
- Transmit a character of strength and follow the receiver. When you transmit this tracking, it is easier for a buyer to trust the solution offered by your products.

The presence of this shield will only be present in the graphic documents, because inside the watch, being of a very small size, it will be dispensed with. This can best be seen in the 8 mm test that will be performed next, where, as the icon becomes smaller, this shield should be dispensed with not to impair its readability.

## 6.3 The brand colours

As explained in the previous section, what is intended to transmit with this brand is the relationship with the world of the sea, specifically with the Mediterranean Sea, the place of creation of the product. The Mediterranean Sea through history, has been associated with some main colours, these are the ultramarine blue and white glacier.

That is why they have been used as predominant colours. A characteristic dark blue in the jewellery companies but still representing the maritime tones and a white slightly darkened not to generate a contrast so marked between both colours.

As a complementary colour, a golden gradient has been chosen for the details that can be seen in the following sections. In addition, this is a colour that accompanies the product, reason why its presence was necessary in the image of the mark.

The Pantone, CMYK, RGB and HTML codes are listed below in the following order:

### Dark Blue

- **Pantone P 282-C**
- C96-M97-Y56-K43
- R20 G26 B55
- #141A37



### White

- **Pantone P 179-1C**
- C4-M4-Y3-K0
- R247 G247 B247
- #F7F7F7



### Gold

- **Pantone P 10122-C**
- C30-M39-Y77-K0 : C4-M30-Y58-K0
- R185 G158 B91 : R236 G196 B128
- #B99E5B : ECC480





## 6.4 Typography



For typography a selection has been made with typographies that break a bit with the classic aesthetics of the clock and symbolize the modernity of the technology present in the clock. In this way, the classic look is represented with a rudder and a more modern look, in this case based on its typography.

In the process of finding a suitable typography for the brand logo, it was very important that it be as clear as possible, because it should be present on the watch face in a very small size.

### 6.4.1 Selection of typography

In this way 3 fonts were chosen that meet the requirements of being clear, clear, modern fonts that are easy to read at very small sizes. Once these 3 types are selected, a study will be carried out to select one of them.

The fonts chosen for this study were: **Lato**, **Roboto** and **Clear Sans**

## Lato

ABCDEFGHIJKLMNOPQRSTUVWXYZ  
abcdefghijklmnopqrstuvwxyz

## Roboto

ABCDEFGHIJKLMNOPQRSTUVWXYZ  
abcdefghijklmnopqrstuvwxyz

## Clear Sans

ABCDEFGHIJKLMNOPQRSTUVWXYZ  
abcdefghijklmnopqrstuvwxyz

Figure. 38 Final typography proposals

In this way, following the classification used by Aldo Novarese in 1958, the three typographies selected correspond to the linear family, that is to say that they do not present finials in their extremities, nor apices in their crests.

These typographies allow reading from very small sizes, and this is what is sought because the company logo will appear in the case of the watch next to its isotype.

Following with the selection, the first typography that was discarded was the Roboto. Ideal typography for document titles, but that does not just have a good finish as the main typeface for a logo.

So, we are facing the selection between the Clear Sans and the Lato. Very similar between them and with hardly any differences.

Although one of the differences that marked the difference was the width that occupies a word written in Lato and in Clear Sans, in the following image you can check as in the Clear Sans, in the same size and with the same letters, the space is smaller.



*Figure. 39 Comparison between Clear Sans and Lato*

This aspect was given important importance because the company name is of considerable dimensions, and a reduction of the space while retaining its readability, is a key point for the typography chosen for the project was the Clear Sans.

## 6.5 Final proposal

In this way the proposal for the final image of the brand would be the following:



*Figure. 40 Logo in negative*



*Figure. 41 Logo on white background*

### 6.5.1 Proportions and spacing



Figure. 42 Proportions and spacing

### 6.5.2 Favicon



Figure. 43 Favicon

### 6.5.3 Readability 8 mm



Figure. 44 Readability 8

## 6.6 Documentation



Figure. 45 Example of letter and envelope company



Figure. 46 Example of Contact Cards. White: Front. Blue: Behind

## 6.7 Formal proposal



Figure. 47 Frontal render of the watch



Figure. 48 Inclination of the elements





Figure. 49 Lateral render of the watch

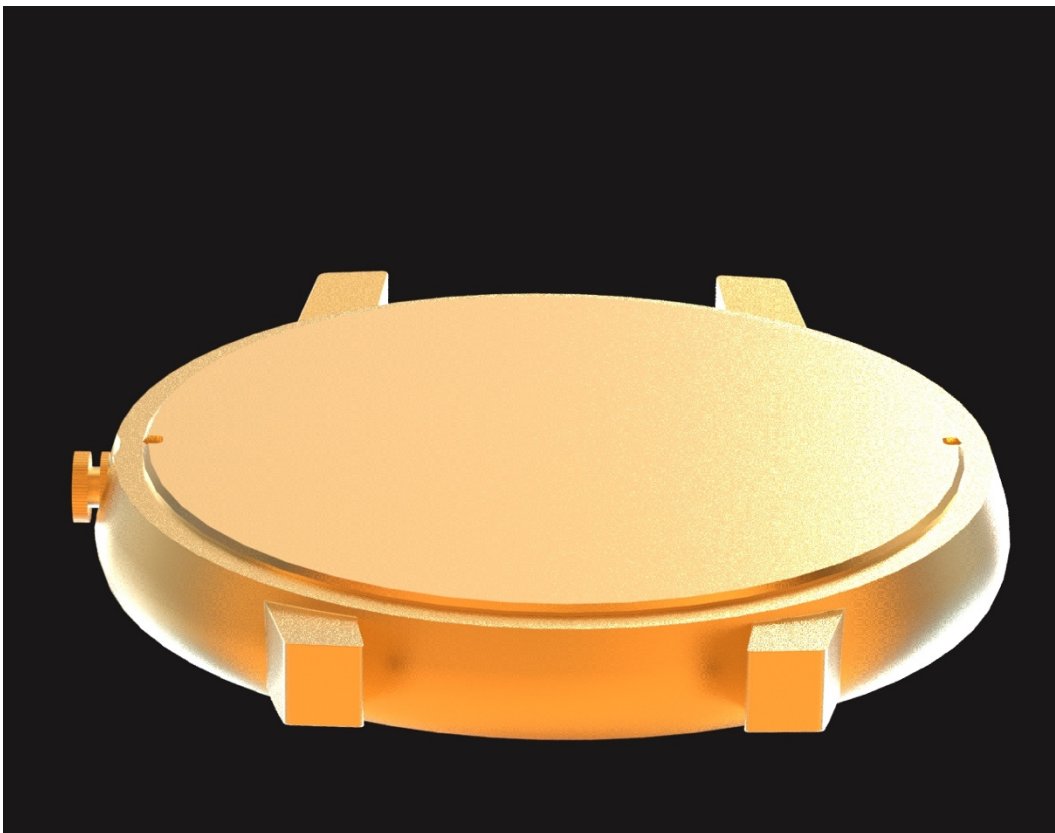
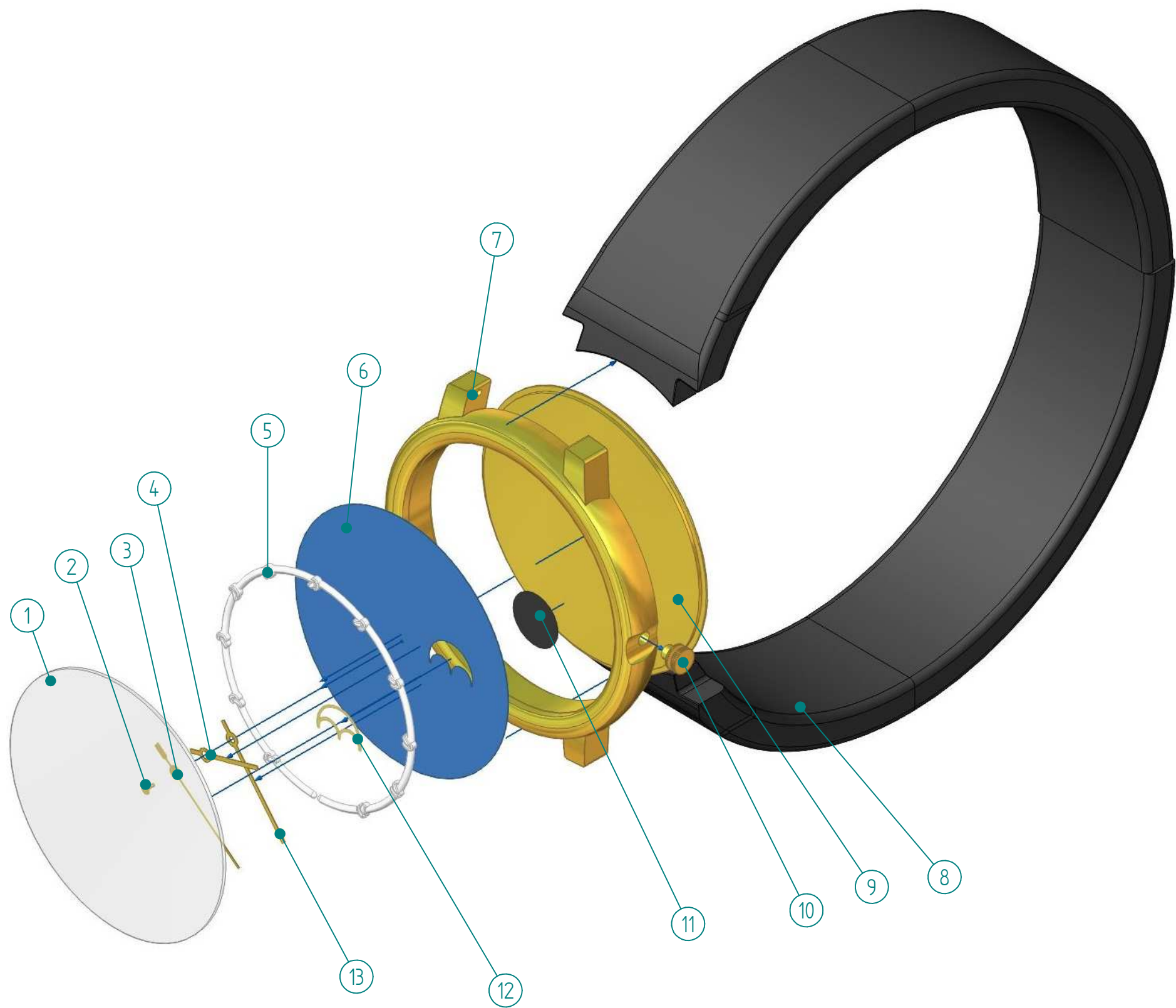


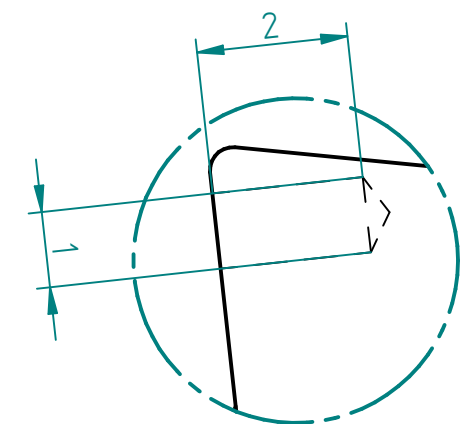
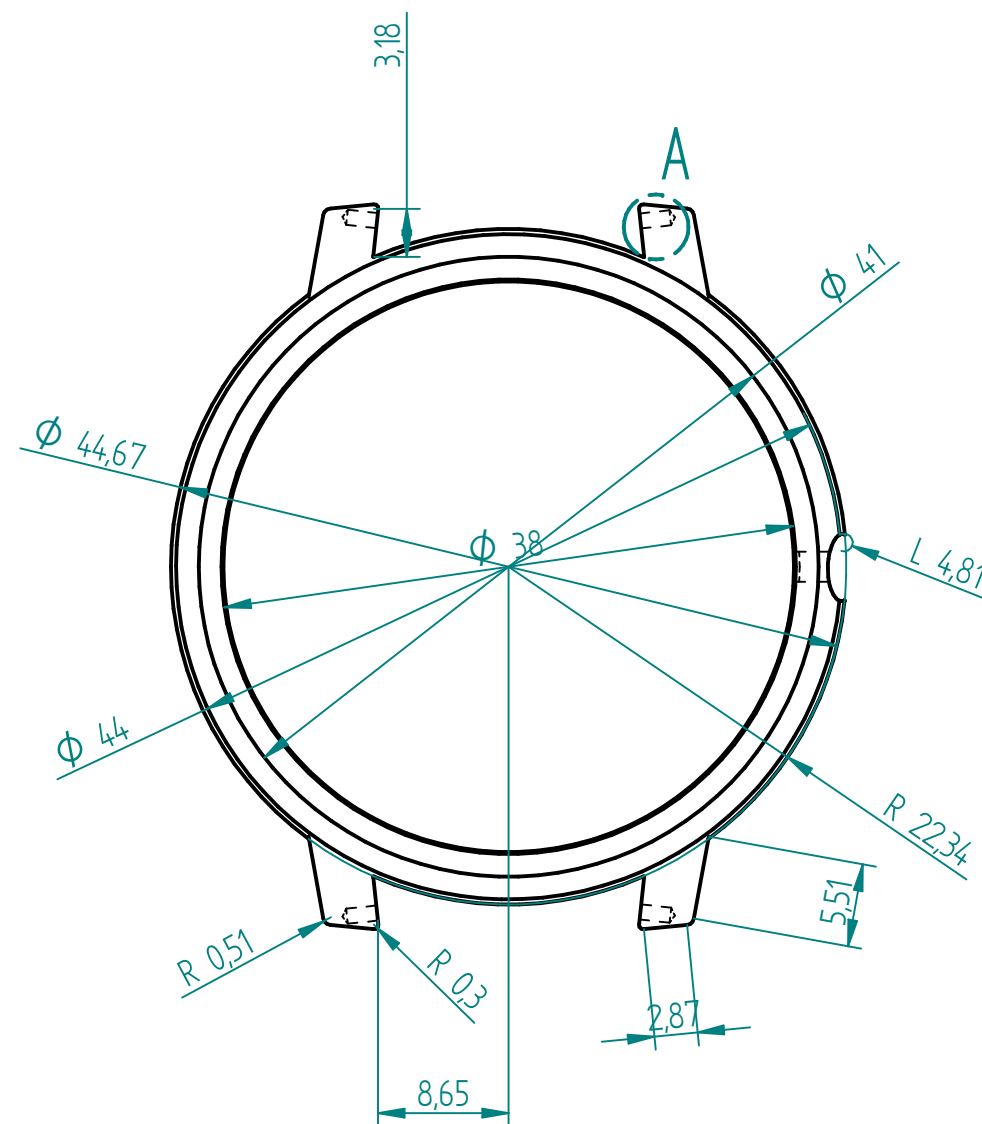
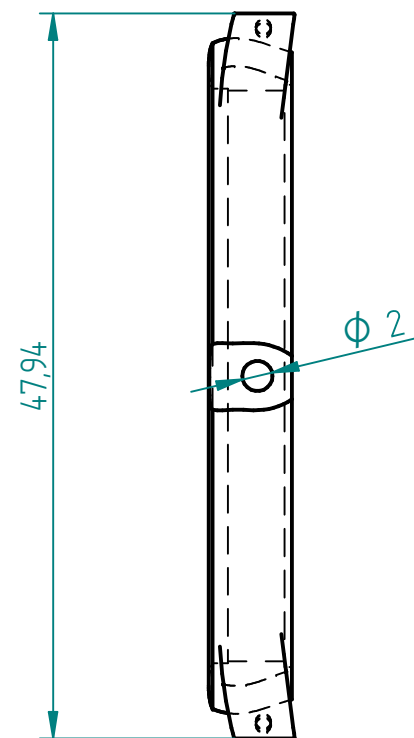
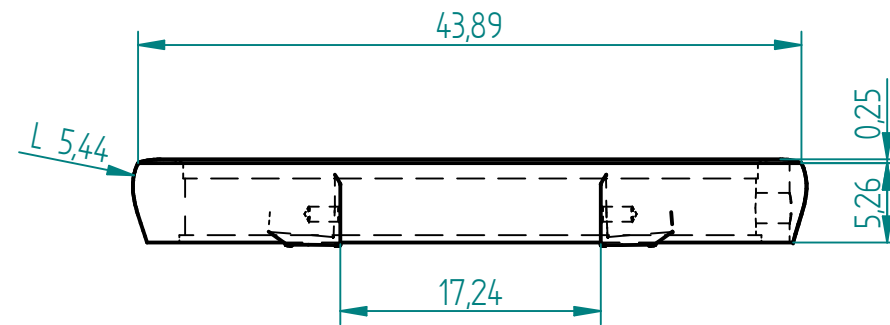
Figure. 50 Back render of the watch

## **7. Technical documentation**

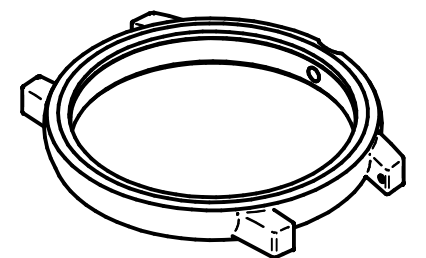


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1	Crystal	1	Synthetic sapphire
2	Support hands	1	Brass
3	Seconds hand	1	Brass
4	Hour hand	1	Brass
5	Boat rope	1	Polyester
6	Dial	1	Brass
7	Case	1	Stainless steel
8	Watch strap	1	Polyethilene
9	Back cover	1	Stainless steel
10	Crown	1	Stainless steel
11	Rotative dial	1	Brass
12	Embellisher	1	Stainless steel
13	Minutes hand	1	Brass

			<b>Solid Edge ST</b> Siemens PLM Software		
Drawn	Aitor Santamarina	Sep 2017	Title <b>Explosion</b>		
Checked					
Approved 1					
Approved 2					
If not stated otherwise, all measurements are in millimeters			A3	Plane	Rev
			Scale	Weight	1/12

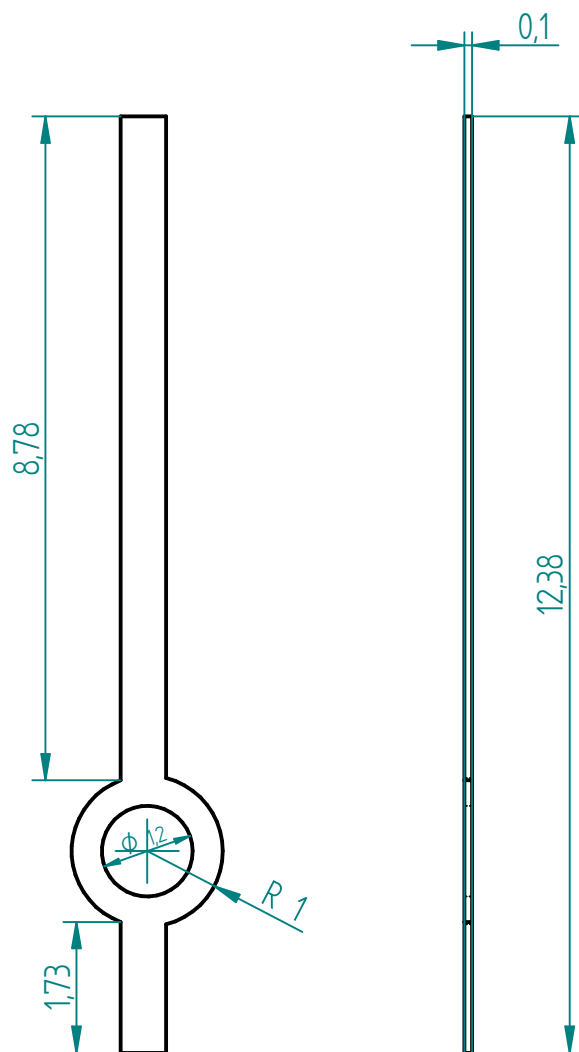


DETALLE A



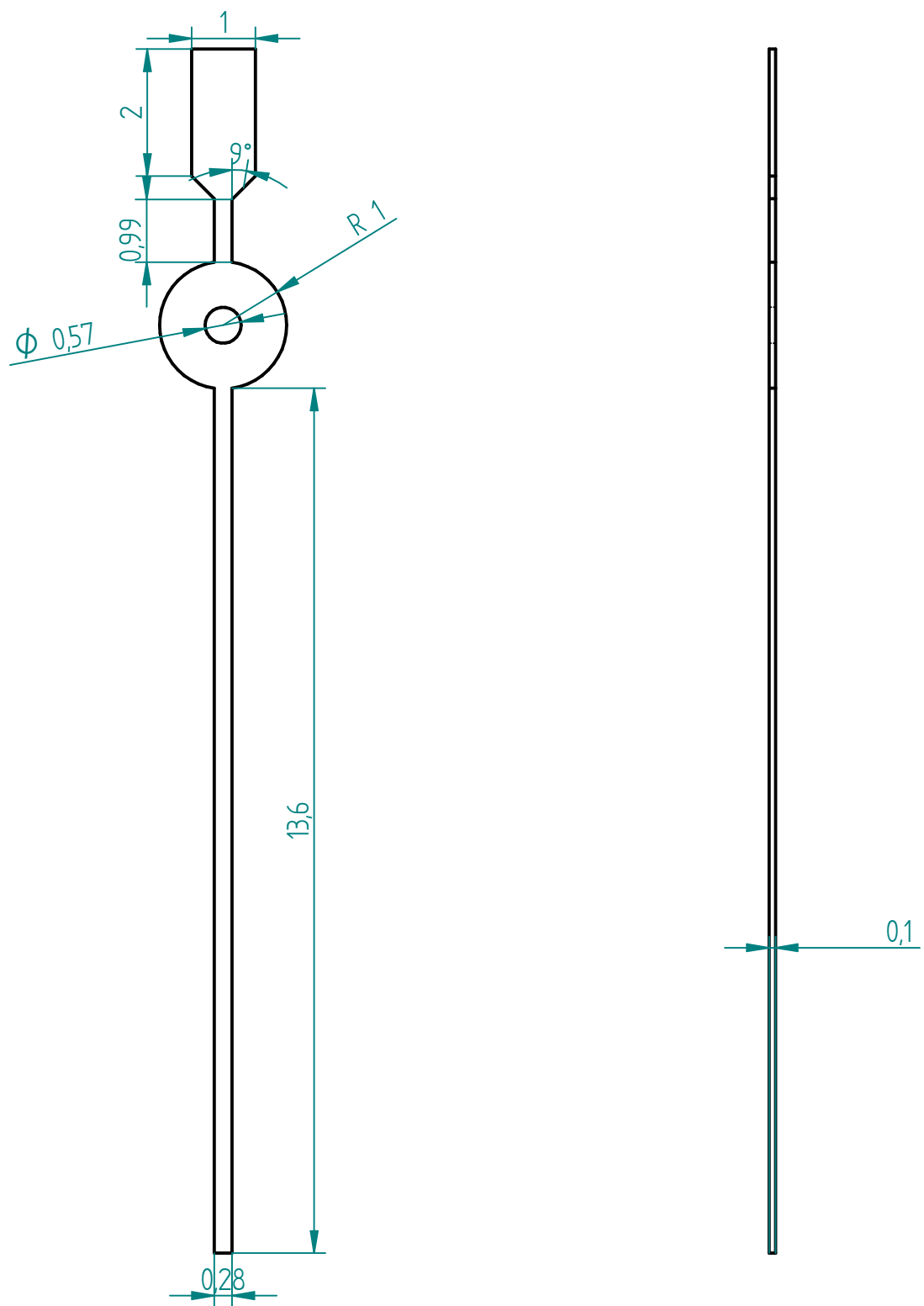
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Approved 2			A3	Plane	Rev
If not stated otherwise, all measurements are in millimeters					
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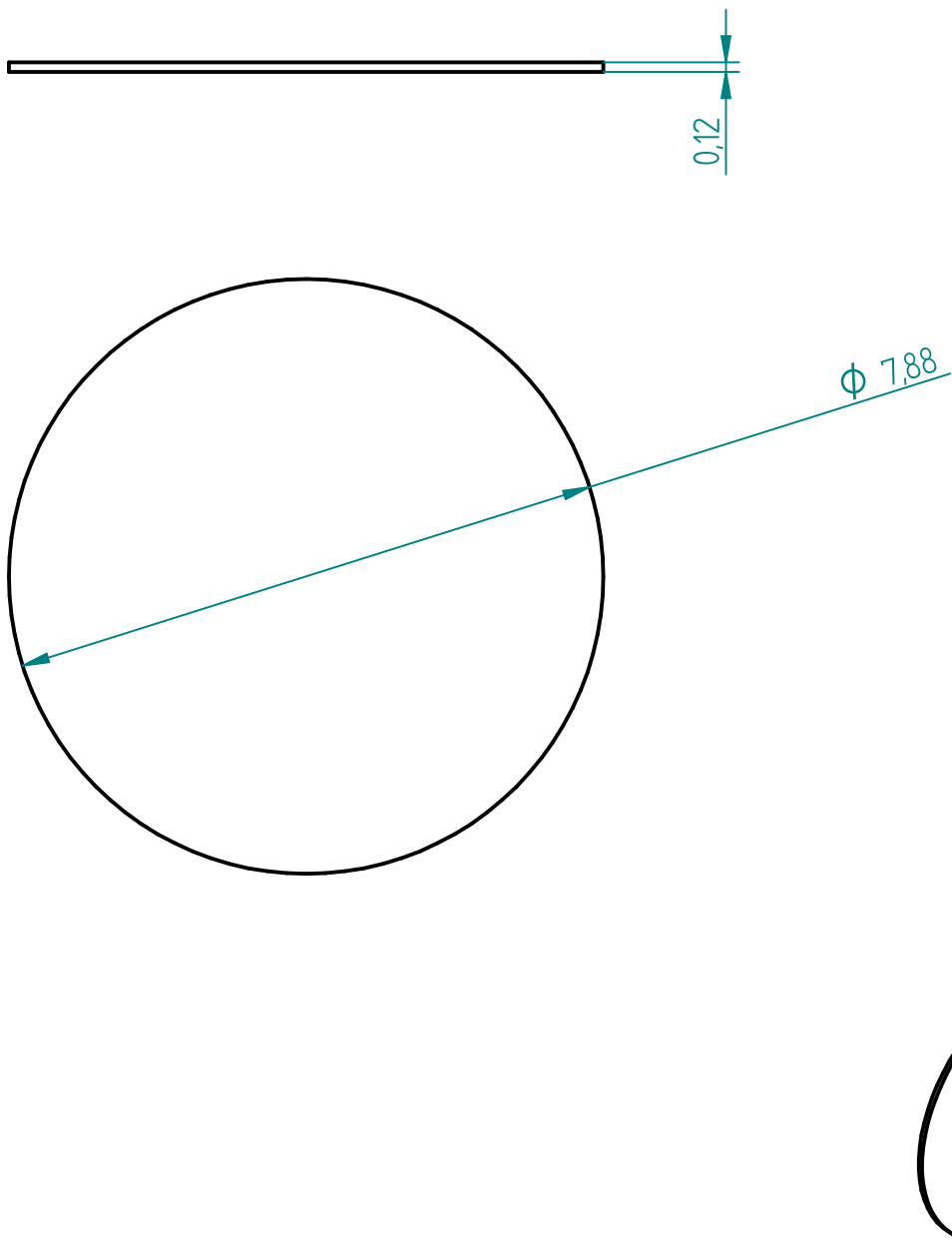
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Approved 2				
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			Rev	
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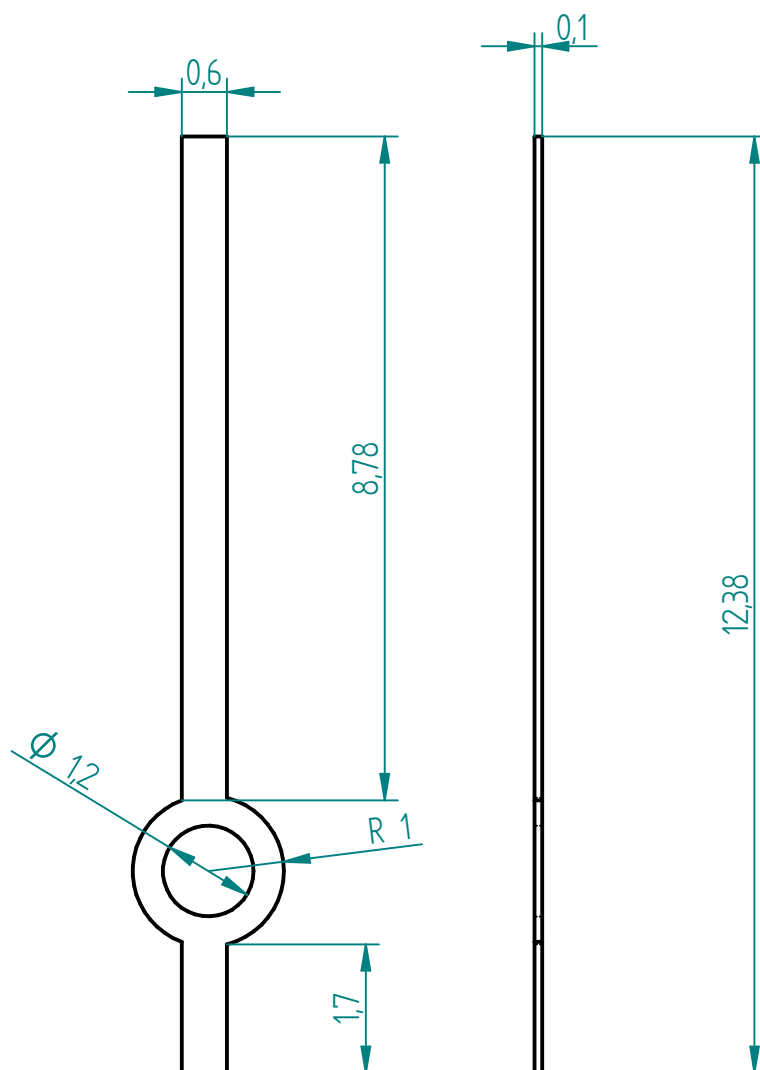


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Checked			Title      Seconds hand	
Approved 1				
Approved 2				
If not stated otherwise, all measurements are in millimeters			A3	Plane
			Rev	
			Scale 10:1	Weight
			4/12	

SOLID EDGE RESISTANCE COPY



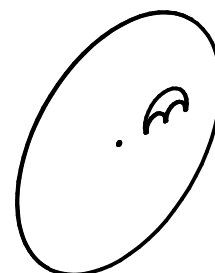
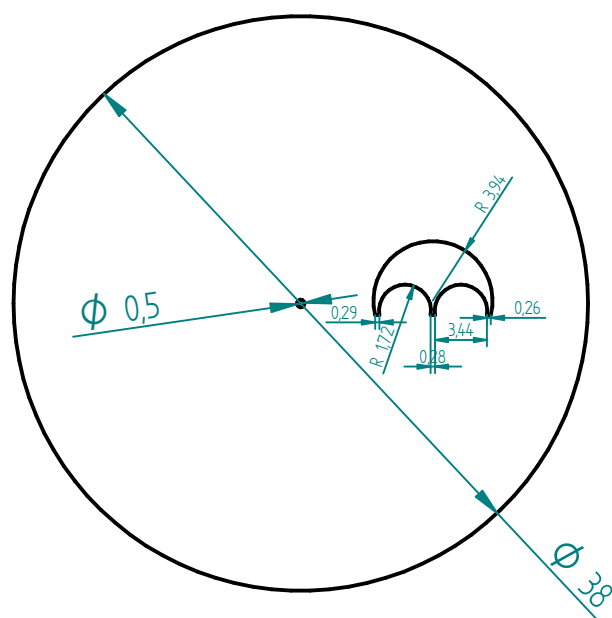
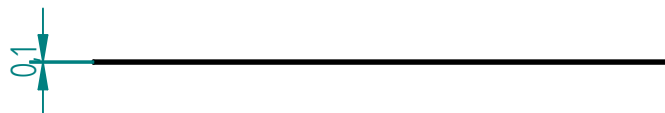
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Approved 1				
Approved 2				
If not stated otherwise, all measurements are in millimeters			A3	Plane
			Rev	
			Scale 10:1	Weight
			5/12	



	Name	Date	<b>Solid Edge ST</b> Siemens PLM Software	
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Approved 2				
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			Rev	
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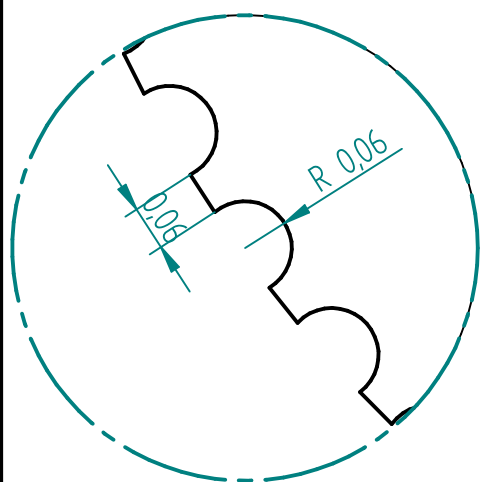
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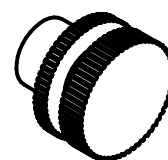
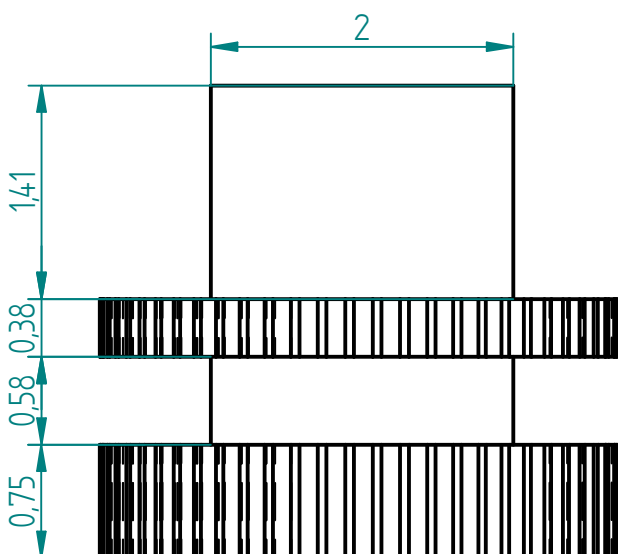
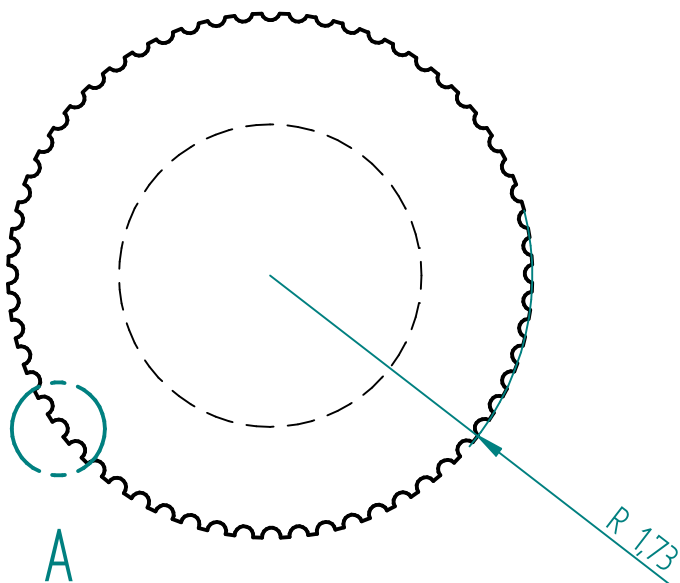


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Approved 1					
Approved 2					
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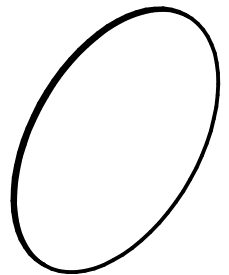
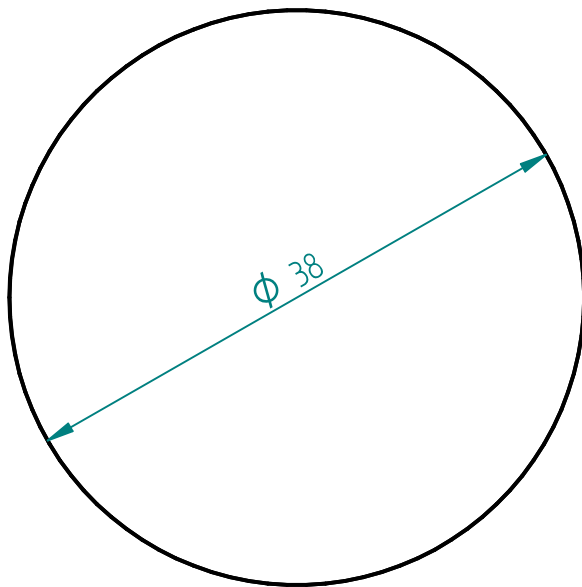
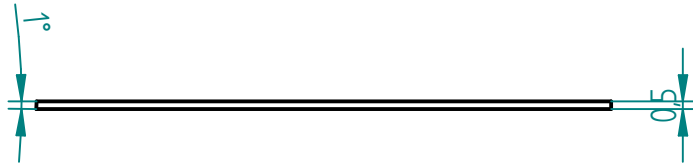


DETALLE A

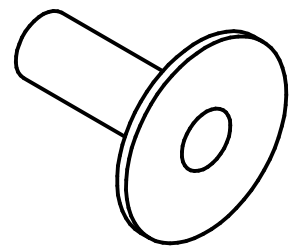
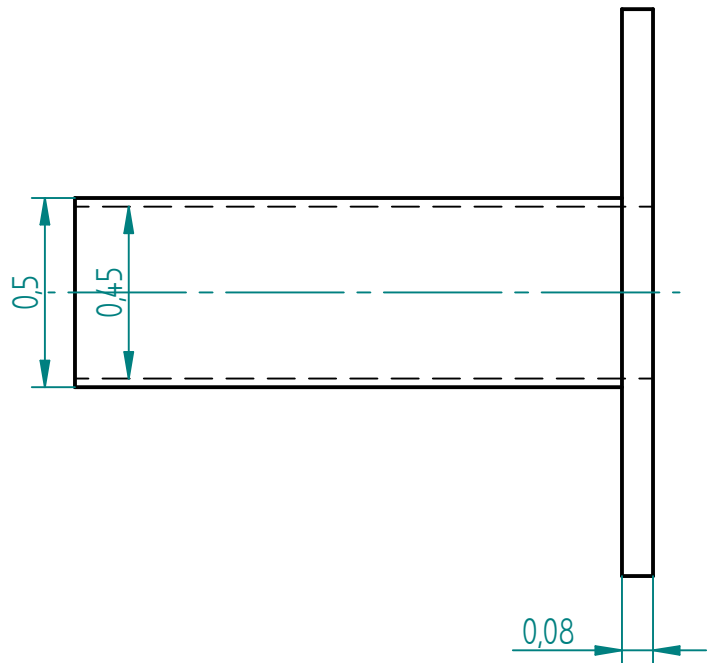
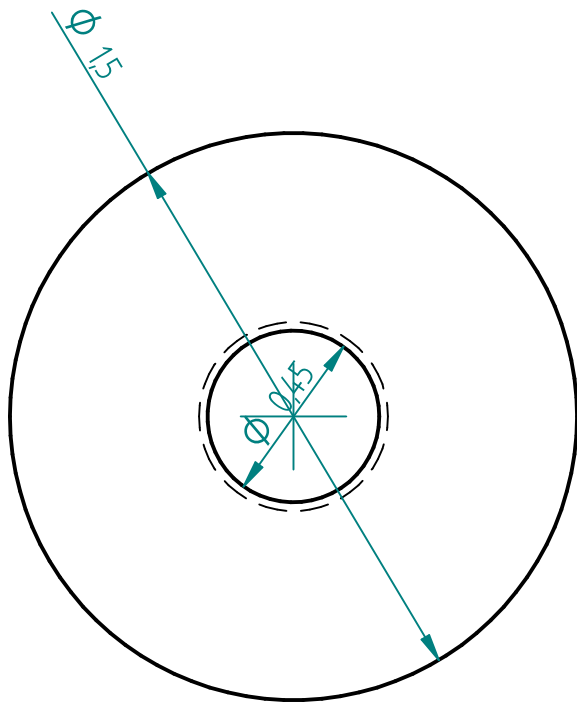


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Approved 2				
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			Rev	
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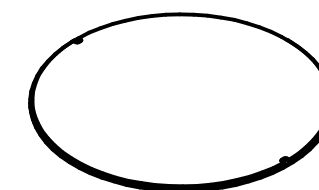
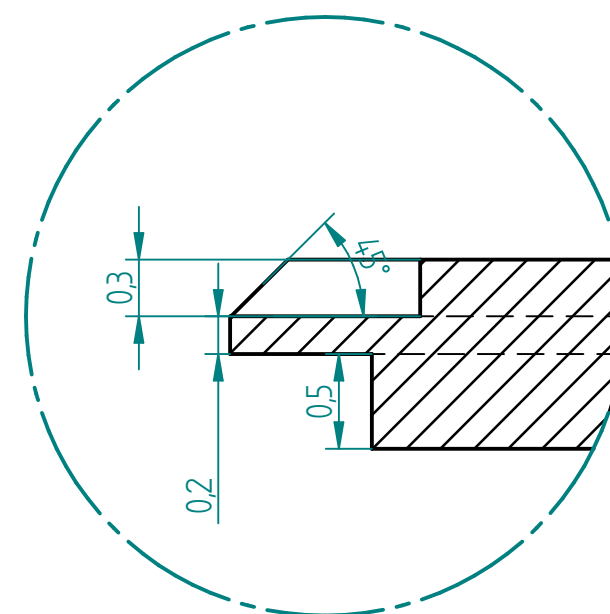
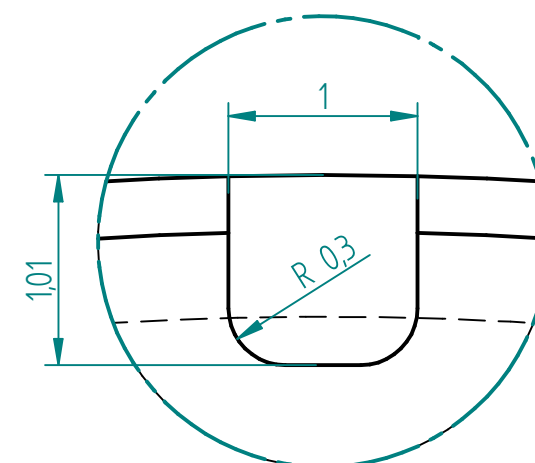
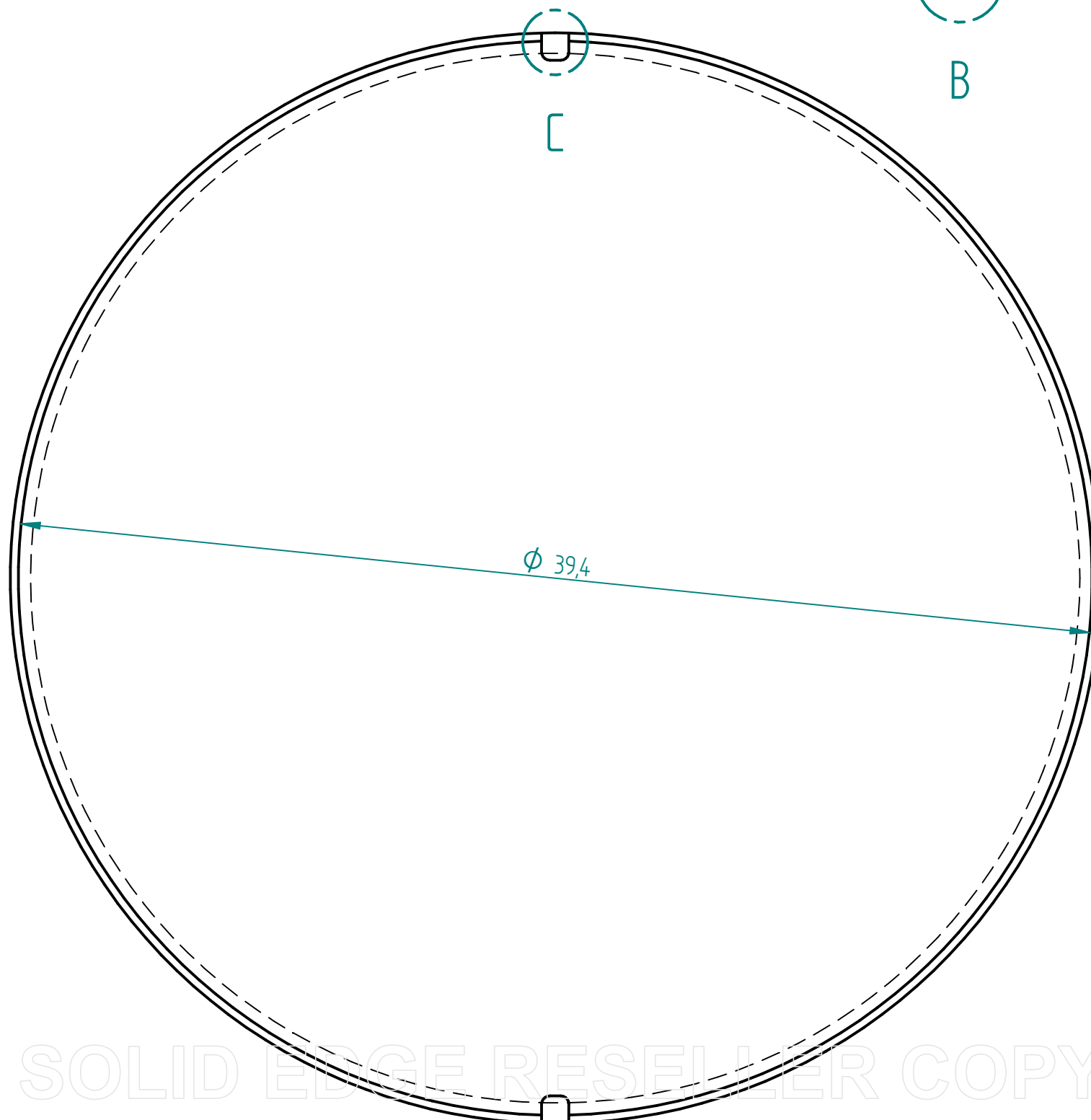
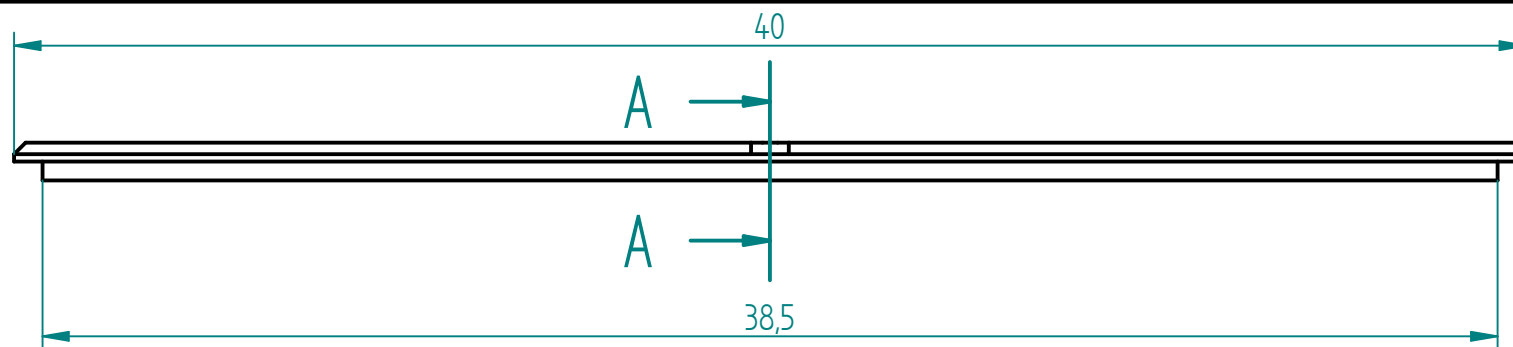


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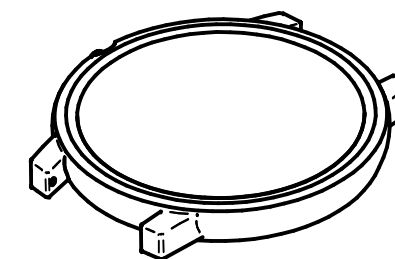
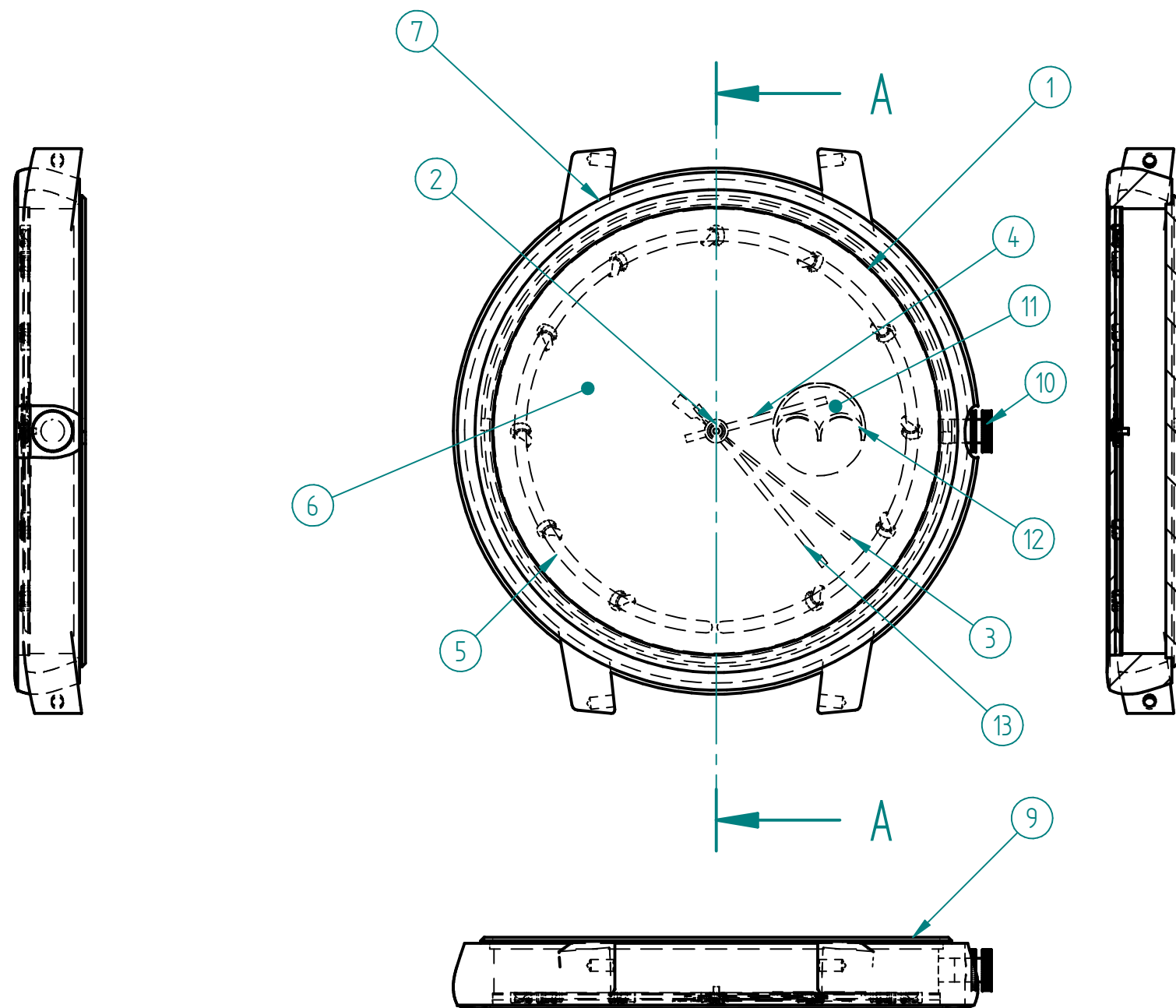
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Approved 1				
Approved 2				
If not stated otherwise, all measurements are in millimeters			A3	Plane
			Rev	
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	Name	Date	<b>Solid Edge ST</b> Siemens PLM Software		
Drawn	Aitor Santamarina	Sep 2017			
Checked			Title Case back		
Approved 1					
Approved 2			A3	Plane	Rev
If not stated otherwise, all measurements are in millimeters					
			Scale 5:1	Weight	11/12

SOLID EDGE RESELLER COPY



#	Description	Parts #	Material
1	Crystal	1	Synthetic sapphire
2	Support hands	1	Brass
3	Seconds hand	1	Brass
4	Hour hand	1	Brass
5	Boat rope	1	Polyester
6	Dial	1	Brass
7	Case	1	Stainless steel
8	Watch strap	1	Polyethylene
9	Back cover	1	Stainless steel
10	Crown	1	Stainless steel
11	Rotative dial	1	Brass
12	Embellisher	1	Stainless steel
13	Minutes hand	1	Brass

			<b>Solid Edge ST</b> Siemens PLM Software		
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Checked			Title <b>Ensemble</b>		
Approved 1					
Approved 2					
If not stated otherwise, all measurements are in millimeters			A3	Plane	Rev
			Scale 2:1	Weight	12/12

## 7.2 Normative

For the development of this proposal must take into account different types of regulations that have a direct relationship with the product.

### 7.2.1 Rules of competition in J/80

On one hand we have the rules of competition in J/80 boats that tell us which objects can be used during a Regatta and the limitations that these must have. The regulations are as follows:

- ISAF Sailing Rules (RRV)
- Cruise Ship Regulations (2015)
- Regulation of the class J-80 Active
- ISAF Security Regulations Category 4º 2016-2017

### 7.2.2 Product development regulations

On the other hand, there is a wide range of regulations regarding the product, whether normative that deals with the material used, norms related to the geometry of the watches, as well as the batteries that they can use. The regulations in question are as follows:

**UNE-EN 1811:2011+A1:2016**- "*Método de ensayo de referencia para la determinación de la liberación de níquel en objetos dotados de pasador que se insertan en partes perforadas del cuerpo humano y en productos destinados a entrar en contacto directo y prolongado con la piel.*"

**UNE-EN 60086-3:2016** - "*Primary batteries - Part 3: Watch batteries (Endorsed by AENOR in November of 2016.)*"

**UNE-EN ISO 463:2006/AC:2009** - "*Especificación geométrica de productos (GPS). Equipos de medición dimensional. Diseño y características metrológicas de relojes comparadores mecánicos. (ISO 463:2006/Cor 1:2007/Cor 2:2009)*"

**UNE 53982:2000** - "*Plásticos. Materiales poliméricos celulares flexibles. Identificación de la base éter o éster de una espuma de poliuretano (PUR).*"

**UNE 53985-5:2008** - "*Plásticos. Ensayos de materias primas para poliuretanos. Polioles. Parte 5: Determinación del contenido en sodio (Na) y potasio (K)*"

## **8. Industrialization study**



In this section will proceed to conduct a study of the industrialization of the product. In this way, it will be considered how the manufacture and implementation of the proposed solution could be possible.

## 8.1 Sustainability in the manufacturing process



Figure. 51 Sustainability in the manufacturing process

One of the initial premises for the design and development of a product was that it complied with adequate sustainability values, for it is not enough to choose materials that can be recycled later, but there are a number of factors that condition that the whole production process that surrounds the product, is within those values of sustainability. There is no point in using recyclable materials if they will be difficult to separate once the product life cycle has ended.

That is why it is very important to take this into account, so that from the beginning of the production approach of a product, it can become sustainable.

### 8.1.1 Renewable energies as an energy motor

In every productive process, energy is needed to function. It is the implication of the company itself to know how to properly choose the source of this. Therefore, all energy to be used in the facilities of the product, must come from renewable energy sources, such as wind, solar or hydraulic, among others.

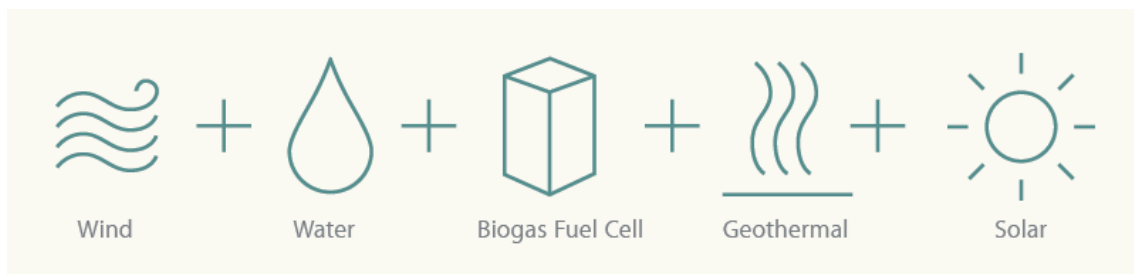


Figure. 52 Use of renewable energy as the main source of energy

The choice of these sources as energy sources not only contributes to the reduction of environmental resources from fossil fuels but also contributes to the reduction of CO2 emissions. The emissions of this gas are the cause

### 8.1.2 The product life cycle

To reduce the number of resources we take from the planet, it is very important to have products with a high percentage of recyclable materials. In this way, we can close the life cycle of the product, generating the least possible impact on the environment, since these materials can be used later for the manufacture of new products.

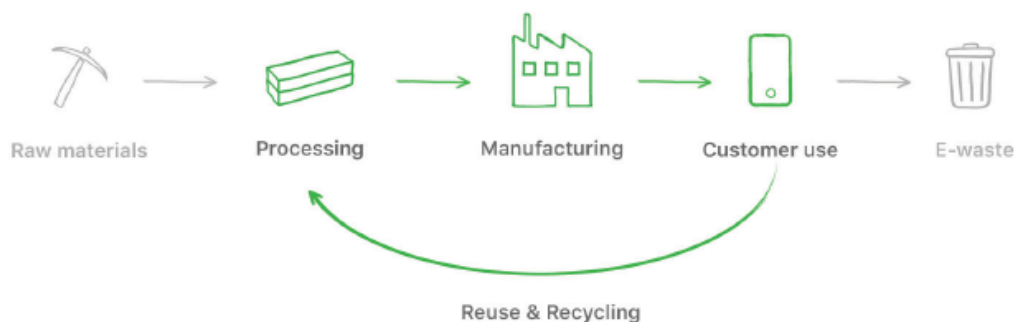


Figure. 53 Closing the loop in the supply chain

As can see in the image above that corresponds to the life cycle, by having recyclable materials, we skip the two most harmful steps in the manufacture of a product: The process of extraction of resources for its manufacture and waste management that these generate once their life cycle has ended. If this circle is closed, the process achieves a 100% sustainable production by not depending on the natural resources.

### 8.1.3 Sustainable design

The process of creating a sustainable product starts from the first steps, from the design of this. This is because while designing a product you have to take into account not only how it will be manufactured, but how once finished its life cycle, this is going to disassemble. The first phase in the recycling stage of a product consists of the separation of the different materials that make it up, so there are two very important factors that facilitate this stage:

- The use of the smallest number of materials: by having a smaller number, the extraction process is reduced.
- The correct choice of fastening methods between components of different material. That is why it is so important to use the smallest number of fixing materials in a product, and to use a suitable design to reduce the use of these. For example, use a thread-locking design on the back of the watch,

and use a silicone. The function during the use of the product will be the same, but one will negatively affect the recycling of the components of the product.

#### **8.1.4 Durable device is a greener device**

It is a fact that the longer the product life cycle, the longer it will take to reach the two most damaging phases of this, and the lesser the impact it will generate. With this in mind, during the design of the watch has been sought to have as long a life as possible. Therefore, different tests will be carried out to test the product and thus detect the most frequent causes of breakage or failure and to be able to apply a solution before it reaches the user.

## 8.2 Fabrication of the case

For the fabrication of the case, stainless steel will be used, as detailed in section (5.10.4 Material selected for the case, page 73).

The process of industrialization begins with ingots of the raw material that melt at a temperature above 1360 °C, later, it will be injected in permanent mould casting, that use the own gravity to introduce the molten material inside the cavities. These moulds are used in hot so the first pieces usually go wrong.

Once it has the desired shape, it is heated in ovens at high temperatures, this must be higher than the critical temperature of Austenization (800°C), but without melting the metal. Then a cold forging process is carried out consisting in reduce very quickly the temperature of the material pouring water when it has just left the oven, in this way, it improves the hardness up to 80% making it more resistant to scratches and bruises.

The next step consists of machining the parts by CNC. This allows greater accuracy when it's cut. This mechanization ensures that the most complicated faces of the piece are perfect.

Then the piece pass in to a process of, this process uses polishers that pass through the entire outer surface giving a look of brightness.

The last step is to give the desired colour to the steel, for this there are different methods depending on the result you want to obtain. For our case the method to be used will be a hot galvanizing, which consists of an electrolytic process in which the piece is bathed in a solution with zinc to oxidize the outer layer and get the gold we are looking for. This oxidation also provides a better resistance to corrosion, since when coating the metal of an already oxidized layer, it protects it from external agents. This is the basic operation of stainless steel.



Figure. 54 machining by CNC

### 8.3 Manufacturing process of polyurethane strap

Polyurethane comes from the mixture of diisocyanate (chemical compounds characterized by having two functional groups  $N = C = O$ ) with different polyols (polyhydric alcohols). There are two types of polyurethanes according to their chemical structure:

- **Thermoset polyurethanes:** When degraded they are decomposed into carbon, so they are materials that cannot be recycled
- **Thermoplastic polyurethanes:** Materials that can melt and form back because they do not degrade upon heating.

The process of making a polyurethane belt begins with the injection into a closed mould of the plastic in liquid form. It is very important to control the presence of air inside the mould to minimize the porosity that can occur.

Further, once the plastic is cooling inside the mould, a flame is passed over the entire outer surface to reduce said porosity.

To finish, when the piece is already cold, proceed to cut the burrs that have occurred during the process

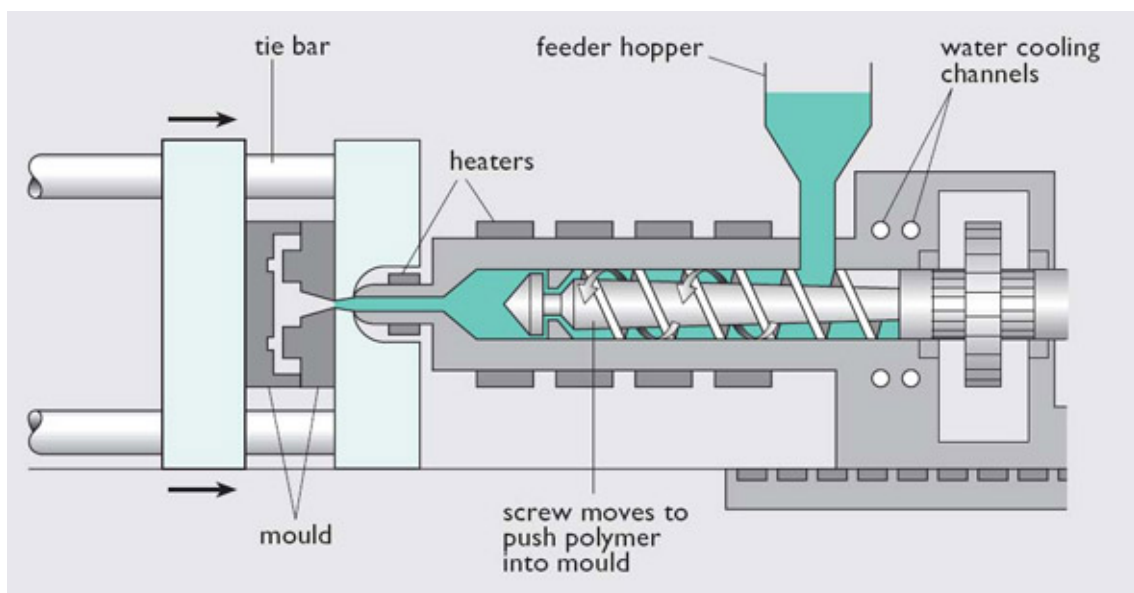


Figure. 55 Manufacturing process of polyurethane strap



## 8.4 Manufacturing Process of Minor Components

### 8.4.1 Manufacturing of the hands

The process begins with a perforation of a Brass plate of three meters long by means of width, to obtain the internal hole of the hand. This perforation is performed with a maximum accuracy of about  $\pm 2 \mu\text{m}$ .

Because they are precision parts and any imperfection could result in the mechanism not working properly, the process to be followed will be numerically controlled laser cutting on a Brass plate with the desired thickness.

These cuts are of a few tolerances so their handling is very delicate.

Later these pieces are introduced in a drum that contains small conical shaped elements, that by the friction that occurs when turning, they polish the surface of the hands.

To finish the work is done, that this is achieved by a treatment of galvanization that includes: washing, degreasing, preparation to the gold and the corresponding dorado (rhodium if the piece is silver).



Figure. 56 Hands of the Breitling brand

#### 8.4.2 Manufacture of sapphire crystal

The manufacture of the sapphire crystal consists of the production of synthetic sapphire by means of furnaces at high temperatures. The process begins by placing a sapphire seed, approximately 100 mm in diameter and 20 in the bottom of a single-use molybdenum barrel. This barrel, called a crucible, is filled with a mixture of corundum condensate (crystalline form of aluminium oxide) and surplus sapphire material.

The filled crucible is placed in an oven seated on a small platform of cold liquid helium that prevents the initial sapphire from melting prematurely. The oven is sealed and air is evacuated from the interior. The temperature rises to 2100 ° C to melt all materials.

The material is then subjected to a series of cooling cycles for about 16 days, at which time the sapphire slowly crystallizes from the bottom up. This achieves a cylindrical section of 115 kg of industrial sapphire called *Boule*.

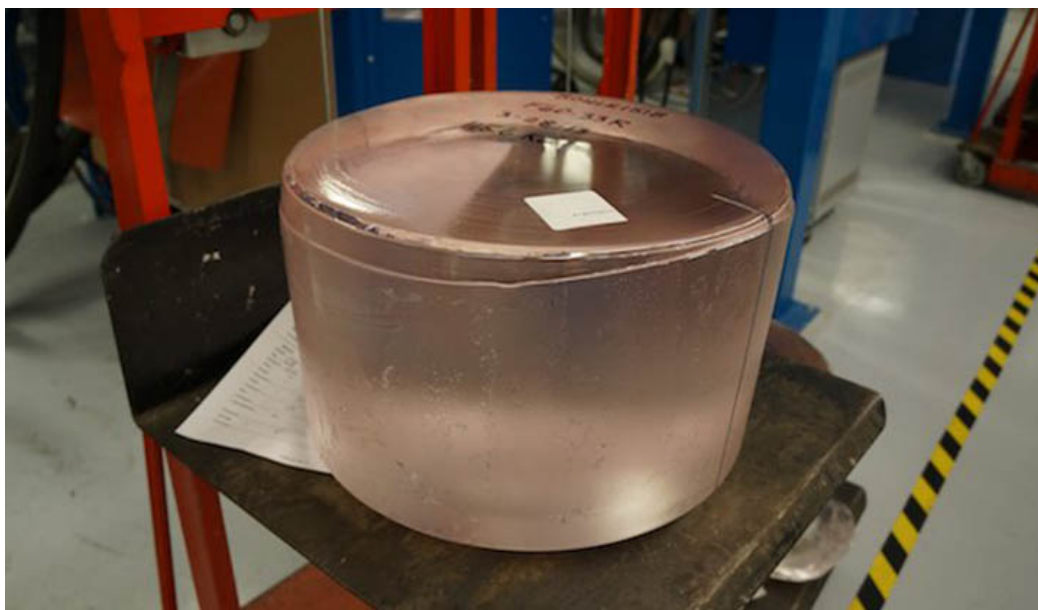


Figure. 57 Boule obtained after the cooling cycle

Sapphire is the second hardest material after diamond, for this reason the last step is to cut this boule to adapt it to the shape that will be used in the watches. For this there are two options, cut it with diamond saws or laser. With one of the two options are cut with a specific dimension's rectangular shapes. The pieces are then polished and cut into slices with an appropriate thickness.

## 8.5 Electronic components

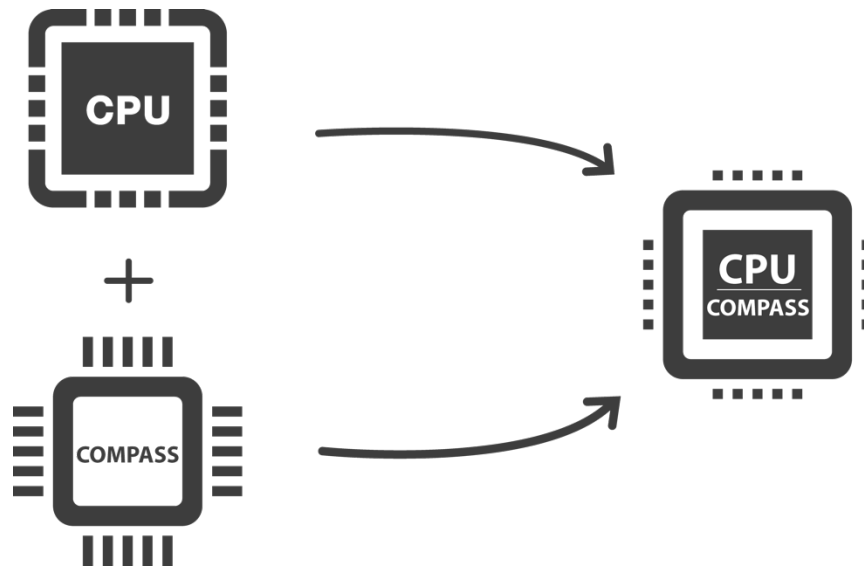


Figure. 58 Union of a processor and a compass chip

As it has been explained in the previous sections, the watch is intended to be a mixture of a classic mechanism with modern functionalities, such as a GPS compass. For this the mechanism will be connected to an electronic circuit that will manage the movement of the mechanism.

In this way the circuit consists of the union of a processor, which will handle the different modes with which the clock counts, with a chip that will provide the compass information.

For the compass, a variation of the Asahi Kasei (AKM) AK8973Sde, a chip that can be found in current Smartphones

Specifically, the chip measures 2.5 millimetres wide and long and 0.5 millimetres thick. In the market there are two models that differ by the number of sensors that act. Most are 3 sensors although the model to be used for the product is the version of 6 sensors, which provides more precision. These sensors are sensitive to magnetism and are placed in six different positions inside the chip. This allows the compass to detect the three axes (X, Y, Z).



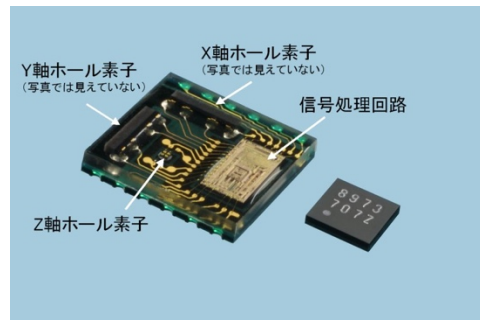


Figure. 59 Chip Asashi Kasei (AKM)

As for the consumption of this is considered to have a low consumption (6.4 mA while operating and 0.8 mA average in measurements with intervals of 100 ms.).

For the manufacture of a chip like this, there are companies that design and manufacture custom electronic components for the customer. This would be the way to obtain this material, subcontracting to an external company that is in charge of the design of this chip. later this will be assembled in the mechanism provided by a different company.

## 8.6 Clock mechanism

For the mechanism of the clock, it will be used of the distributor **ETA SA Manufacture Horlogère Suisse**, company that is in charge to manufacture mechanisms of classic clocks standardized. This company of Swiss origin, designs and manufactures complete mechanisms with quality certificates.

Inside the catalogue there are many options with predefined functions and manuals of assembly of which pieces includes each model, as well as their arrangement in case you want to modify later.

In that range would be this product, that would use a mechanism offered by this brand but with certain modifications that allowed to use the needles of the clock for several modes at the same time.



Figure. 60 Mechanism ETA 2802-1

The mechanism selected for the watch is the **ETA 2801-2**, of a more basic character, its characteristics are the following:

- Hours, minutes, sweep second.
- Regulator system ETACHRON.
- 28.800 vibrations per hour; 4 Hz.
- 17 Jewels.

### **8.6.1. Modification of the ETA mechanism**

The operation of ETA supplier company of personalized mechanisms begins in a negotiation between client and distributor. The company is responsible for making the modifications requested by the customer, if a minimum number of pieces to be purchased are agreed upon.

In this way, the more complicated the modification, the more quantity the customer has to buy for the dealer to make the change.

The change in question that would be made to the original mechanism would be the inclusion of a train of movement that would allow to be able to move the needles independently, thanks to the movement provided by an electronic circuit according to the mode that the user has chosen.

In addition to including a rotary dial on the right side of the watch that will change its position depending on the function you are performing.

## 8.7 Assembly of parts

Once it has all the components of the watch, the next step is to assemble the pieces. This will follow the order provided by the housing.

The first step is to connect the internal mechanism to the electronic component through the drive train. The mechanism will have a rotating element that will engage the function dial. To join it simply place the dial on this part in its proper position.

Once the mechanism is mounted, the elements that will turn the needles are passed through the centre of the outer dial. The outer dial has decorative elements to be mounted in this step, such as the rope with knots that has been previously made.

The glass will be pressurized due to the conical shape of its walls from the inside of the casing to the outside, in this way a good fixation is obtained without having to resort to glues. If the user wants to remove this crystal, it would have to force from inside, so it would have to remove all the components before being able to change said crystal.

The placement of the needles consists of the variation of diameters so that each needle is placed on its suitable rotating element. First place the second hand, then the minute hands and finally the hours.

These components are introduced in the housing, which thanks to the variation of the interior walls, allows a correct positioning of the dial inside the housing.

Finally, the battery is placed and the back cover is closed by means of thread.



*Figure. 61 Assembling the details of a watch*

## 9. Economic Study

## 9.1. Cost of manufacturing the parts

In this section will be made a study of the economic cost that supposes the manufacture of the developed proposal. Because the components of the watch come from outside suppliers, the cost of each item will be counted separately and what the set would cost. These prices are orientative, because it is very difficult to obtain a price 100% real because it depends on the dealer and the parts that are requested the price can change.

### 9.1.1. External elements:

Piece	un	Material	Process	Distribution	Unit price
Crown	1	Stainless steel S316	Injection, Machining, Galvanization		8€
Case	1	Stainless steel S316	Injection, Machining, Galvanization		35€
Correa	1	Polyethylene	Injection and Machining		11€
Crystal	1	Synthetic sapphire		DJ Laser	7€
					<b>TOTAL: 61€</b>

Table. 10 External elements cost

### 9.1.2 Internal elements

Piece	un	Material	Process	Distribution	Unit price
Mechanism	1	Various	Injection, Machining, Galvanization	ETA	65€
Hands	1	Brass	Laser cutting, polishing		2€
Dial	1	Aluminium	Laser cutting, polishing, varnished		3€
Rotary dial	1	Aluminium	Laser cutting, polishing, varnished		2,5€
Chip	1	-		CNM	20€
					<b>TOTAL: 92,5€</b>

Table. 11 Internal elements cost

### 9.1.3 Complementary elements

Piece	un	Material	Process	Distribution	Unit price
Boat string	1	Polyester	Extrusion and tissue	Sani Amani Craft	1€
Battery	1			Wholesaler	0,50€
Screws	1	Steel	Machining		0,50€
					<b>TOTAL: 2€</b>

Table. 12 Complementary elements cost

**Total:** 155,5€

Following the prices indicated in the tables above, the cost of each component of the watch would cost € 155.50 per watch.

## 9.2 Amortization

In order to know what would be the investment needed to stop relying on external distributors and to know from which quantity produced would be more profitable to buy the machinery to manufacture the components, an amortization study has been carried out that collects the price of the necessary machinery for the most important components. At this price should be added other extras such as the cost of operators or the cost of space needed to assemble this machinery.

### 9.2.1 Case and crown machine

Process	Tools	Price
Injection in closed chamber	Mould	30.000€
Machining	Machining machine	15.000€
		<b>TOTAL: 45.000€</b>

Table. 13 Case and crown machine cost

### 9.2.2 Machinery Watch Strap

Process	Tools	Price
Injection mould	Mould	40.000€
Asthenization	Oven	1.000€
Machining	Machining machine	15.000€
Polish	Polisher	626€
Hot galvanized	Zinc Alkaline Electrolytic	11.000€
		<b>TOTAL: 67.626€</b>

Table. 14 Machinery Watch Strap Cost

### 9.2.3 Machinery Handles

Process	Tools	Price
Laser cut	Laser cutter	600€
Polish	Drum Polisher	50€
		<b>TOTAL: 650€</b>

Table. 15 Machinery Handles Cost

**TOTAL: 113.276€**

This would be the price that would cost the machinery to be able to produce these components. But it would not take into account the inner mechanism of the watch and the manufacture of the sapphire crystal.

The first requires, in addition to an investment in machinery, an investment in the creation of a project that designs a mechanism suitable for the product, and the second requires an investment in time and space that in the long run would not be profitable seeing the amount needed for the possible flow of production.



### 9.3 Hours and operators required for the process

The next step is to know the cost of the operators to carry out the assembly of the components. For this, the assembly process has been divided according to the steps to be performed, and the assembly time has been distributed in 3 operators. In this way each operator can specialize much more in a particular part of the assembly and thus obtain a better quality and greater production.

Operator 1	Time in seconds
Welding of electronic material with the mechanism	120"
	<b>TOTAL: 120"</b>
Operator 2	Time in seconds
Placing the dial	10"
Placing hands	15"
Decorative rope laying	50"
Placing crystal sphere	10"
Placement of the mechanism inside the housing	15"
Attaching the battery	15"
Placing the cover	5"
	<b>TOTAL: 120"</b>
Operator 3	Time in seconds
Mounting the belt	60"
Start-up and comprobation	60"
	<b>TOTAL: 120"</b>

Table. 16 Timing of operators in the assembly process

In this way the time used for the assembly of the watch is 360 Seconds, this means 6 minutes per piece, so the production would be 10 clocks / hour. If the price of the hour of each operation is 12 €:

- 1 Operator Hour => 12 € / Hour => 10 Units / Hour

**Assembly of the watch 1,2 € / Unit**

## **10. Improvement proposal**

In this work the proposal of a single model of a product has been realized, centred for a very concrete user with very determined colours. As a proposal for improvement would arise variants of this, whether with a second smaller size that best suits the wrist size of a female audience, as different ranges of colours for each type of user.

The same thing would happen with the straps. These have been thought by a very standardized measure, but following the tables that we find in the section of the anthropometric study, we find great variations in the diameter of the dolls, both between genders, and in the same gender. That is why different sizes would also be developed to better suit each user.

This proposal is aware that there are many points that are not just well defined. Especially in the subject of the mechanism of the clock. An improvement proposal would be to use more resources to make a proposal as real as possible. Although the complexity that this supposes is a handicap for the development, because it is a field of very specific watch that would give for a long work.

## 11. Conclusions

In this work we have been able to see all the development that a design proposal of a product entails. Starting with the approach of an environment, following the search for a problem, and the whole study that entails finding a real solution to the problem posed.

Within this document, very different aspects are taken into account in the development cycle of a product, since it is not only a question of finding a proposal, but also how it can be carried out, how to make an idea real emerged behind a creative process. For this reason, both the materials used for this proposal and the manufacturing, budget and regulatory study to be carried out are taken into account.

This serves to have a complete and detailed view of all the branches that encompass a product.

This work is as personal as it has been and it reflects everything I have learned, worked and studied over the years.

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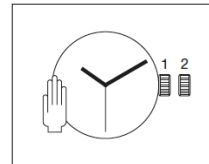
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## Attachments

# Datasheet mechanism ETA MECALINE 2801-2<sup>1</sup>

11 1/2" Ø 25,60 mm



Hauteur sur mouvement	Höhe auf Werk	Movement height	3,35 mm
Réserve de marche	Gangreserve	Running time	42 h
Nombre de rubis	Anzahl Rubine	Number of jewels	17
Angle de levée du balancier	Hebungswinkel der Unruh	Angle lift of balance	50°
Fréquence	Frequenz	Frequency	28'800 A/h

## Liste c

Pos	Numéro d'article Artikelnummer Article number		Liste des fournitures	Bestandteilliste	List of components
1	Var		Platine, montée	Werkplatte, montiert	Main plate, assembled
1-1	7613226044203	2x	Fixateur de cadran	Zifferblatthalter	Dial Fastener
1-2	7613226130272		Amortisseur empierré de balancier, à chasser, à portée, dessous NIVACHOC-B2	Stosssicherung mit Stein, für Unruh, zum Einpressen, mit Auflage, unten NIVACHOC-B2	Jewelled shock-absorber, for balance, shouldered, to press in, bottom NIVACHOC-B2
2	7613226053519		Pignon coulant	Kupplungstrieb	Sliding pinion
3	7613226057111		Pignon de remontoir	Aufzugtrieb	Winding pinion
4	Var		Tige de remontoir	Aufzugwelle	Winding stem
5	7613226016064		Commande du correcteur de quantième	Schalthebel für Datumkorrektor	Date corrector operating lever
6	7613226048171		Tirette	Winkelhebel	Setting lever
7	7613226046504		Bascule de correcteur	Korrektoriwippe	Corrector yoke
8	7613226018693		Sautoir de tirette	Winkelhebelraste	Setting lever jumper
9	7613226056473		Roue d'échappement	Hemmungsrad	Escape wheel
10	7613226041271		Roue intermédiaire	Zwischenrad	Intermediate wheel
11	7613226051010		Roue moyenne	Kleinbodenrad	Third wheel
12	Var		Roue de seconde	Sekundenrad	Second wheel
13	Var		Pont de rouage, empierré	Räderwerkbrücke, mit Steinen	Train wheel bridge, jewelled
14	7613226003002		Barillet complet	Federhaus vollständig	Barrel complete
15	7613226043121		Levier stop	Stopphebel	Stop lever
16	Var		Pont de barillet, empierré	Federhausbrücke, mit Steinen	Barrel bridge, jewelled
17	7613226047297		Cliquet	Klinke	Click
18	7613226051799		Ressort de cliquet	Klinkenfeder	Click spring
19	7613226051744		Bague de roue de couronne	Kronradring	Crown wheel ring
20	Var		Roue de couronne	Kronrad	Crown wheel
21	Var		Rochet	Sperrrad	Ratchet wheel
22	7613226023642		Ancre de chronomètre	Chronometer Anker	Pallet fork for chronometer
23	Var		Pont d'ancre, empierré	Ankerbrücke, mit Stein	Pallet bridge, jewelled
24	7613226015425		Balancier réglé, avec piton, normalisé	Unruh reguliert, mit Spiralklötzchen, genormt	Timed balance regulated, with stud, standardized
25	Var		Pont de balancier, monté	Unruh-Brücke, montiert	Balance bridge, assembled
25-1	Var		Pont de balancier	Unruh-Brücke	Balance bridge
25-2	7613226046092		Porte-piton	Spiralklötzchenträger	Stud support
25-3	7613226048713		Raquette inférieure montée	Unterer Rückerstift montiert	Lower index, assembled
25-4	Var		Raquette supérieure	Oberer Rückerstift	Upper index
25-5	7613226010697		Correcteur de raquette	Rückerkorrektor	Regular corrector
26-6	7613226039902		Amortisseur empierré de balancier, à chasser, à portée, dessus NIVACHOC-B1	Stosssicherung mit Stein, für Unruh, zum Einpressen, mit Auflage, oben NIVACHOC-B1	Jewelled shock-absorber, for balance, shouldered, to press in, top NIVACHOC-B1
26	7613226074163		Renvoi	Zeigerstellrad	Setting wheel
27	Var		Chaussée avec roue entraîneuse	Minutenrohr mit Mitnehmerrad	Cannon pinion with driving wheel
28	7613226031128		Roue de minuterie	Wechselrad	Minute wheel
29	Var		Roue des heures, montée	Stundenrad, montiert	Hour wheel, assembled
30	7613226033085		Pont de rouage de minuterie	Wechselradbrücke	Minute train bridge
31	7613226021778		Clavette	Klemmscheibe	Key-bolt

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<https://secure.eta.ch/CSP/DesktopModules/ViewDoc.aspx?tabindex=1&tabid=28&DocId=199&DocType=DT>

32	7613226055933		Support de cadran	Träger für Zifferblatt	Dial support
900	Var	1x	Vis à tête conique - Pos. 8: Vis pour sautoir tirette	Senkschraube - Pos. 8: Schraube für Winkelhebelras- te	Countersunk head screw - Pos. 8: Screw for setting lever jumper
901	Var	2x	Vis à tête conique - Pos. 13: Vis pour pont de rouage	Senkschraube - Pos. 13: Schraube für Räder- werkbrücke	Countersunk head screw - Pos. 13: Screw for train wheel bridge
		3x	- Pos. 16: Vis pour pont de barillet	- Pos. 16: Schraube für Federhaus- brücke	- Pos. 16: Screw for barrel bridge
		2x	- Pos. 23: Vis pour pont d'ancre	- Pos. 23: Schraube für Ankerbrücke	- Pos. 23: Screw for Pallet bridge
		1x	- Pos. 25: Vis pour pont de balancier	- Pos. 25: Schraube für Unruh-Brücke	- Pos. 25: Screw for balance bridge
902	Var	1x	Vis à tête cylindrique - Pos. 20: Vis pour roue de couronne	Zylinderkopfschraube - Pos. 20: Schraube für Kronrad	Cylindrical head screw - Pos. 20: Screw for crown wheel
903	Var	1x	Vis à tête cylindrique - Pos. 21: Vis pour rochet	Zylinderkopfschraube - Pos. 21: Schraube für Sperrad	Cylindrical head screw - Pos. 21: Screw for ratchet wheel
<b>Pos</b>	<b>Numéro d'article Artikelnummer Article number</b>		<b>Liste des fournitures</b>	<b>Bestandteilliste</b>	<b>List of components</b>
904	Var	1x	Vis à tête cylindrique portée - Pos. 30: Vis pour pont de rouage de minuterie	Zylinderkopfschraube mit Schaft - Pos. 30: Schraube für Wech- selradbrücke	Cylindrical head screw shouldered - Pos. 30: Screw for Minute train bridge
	Var		Variante	Variante	Variant

L'interchangeabilité et les  
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## Datasheet of 316 Stainless Steel<sup>2</sup>

Physical Properties	Metric	English	Comments
Density	8.00 g/cc	0.289 lb/in <sup>3</sup>	

Mechanical Properties	Metric	English	Comments
Hardness, Rockwell B	79	79	
Tensile Strength, Ultimate	580 MPa	84100 psi	
Tensile Strength, Yield	290 MPa	42100 psi	
Elongation at Break	50 %	50 %	in 50 mm
Tensile Modulus	193 GPa	28000 ksi	
Izod Impact	129 J	95.1 ft-lb	
Charpy Impact	105 J	77.4 ft-lb	V-notch

Electrical Properties	Metric	English	Comments
Electrical Resistivity	0.0000740 ohm-cm	0.0000740 ohm-cm	at 20°C
Magnetic Permeability	1.008	1.008	at RT

Thermal Properties	Metric	English	Comments
CTE, linear 	16.0 µm/m-°C	8.89 µin/in-°F	
	@Temperature 0.000 - 100 °C	@Temperature 32.0 - 212 °F	
	16.2 µm/m-°C	9.00 µin/in-°F	
	@Temperature 0.000 - 315 °C	@Temperature 32.0 - 599 °F	
	17.5 µm/m-°C	9.72 µin/in-°F	
	@Temperature 0.000 - 540 °C	@Temperature 32.0 - 1000 °F	
Specific Heat Capacity	0.500 J/g-°C	0.120 BTU/lb-°F	
	@Temperature 0.000 - 100 °C	@Temperature 32.0 - 212 °F	
Thermal Conductivity	16.3 W/m-K	113 BTU-in/hr-ft <sup>2</sup> -°F	
	@Temperature 100 °C	@Temperature 212 °F	
Melting Point	1370 - 1400 °C	2500 - 2550 °F	
Solidus	1370 °C	2500 °F	
Liquidus	1400 °C	2550 °F	
Maximum Service Temperature, Air	870 °C	1600 °F	Intermittent
	925 °C	1700 °F	Continuous Service

Component Elements Properties	Metric	English	Comments
Carbon, C	<= 0.080 %	<= 0.080 %	
Chromium, Cr	16 - 18 %	16 - 18 %	

<sup>2</sup> Source | <http://www.matweb.com/search/DataSheet.aspx?MatGUID=50f320bd1daf4fa7965448c30d3114ad&ckck=1>

Iron, Fe	61.8 - 72 %	61.8 - 72 %	As Remainder
Manganese, Mn	<= 2.0 %	<= 2.0 %	
Molybdenum, Mo	2.0 - 3.0 %	2.0 - 3.0 %	
Nickel, Ni	10 - 14 %	10 - 14 %	
Phosphorous, P	<= 0.045 %	<= 0.045 %	
Silicon, Si	<= 1.0 %	<= 1.0 %	
Sulfur, S	<= 0.030 %	<= 0.030 %	

**Material Notes:** Molybdenum content increases resistance to marine environments. High creep strength at elevated temperatures and good heat resistance. Biocompatible. Fabrication characteristics similar to Types 302 and 304.

**Applications:** food and pharmaceutical processing equipment, marine exterior trim, surgical implants, and industrial equipment that handles the corrosive process chemicals used to produce inks, rayons, photographic chemicals, paper, textiles, bleaches, and rubber.

**Corrosion Resistance:** better corrosion resistance than 302 and 304; resists sodium and calcium brines; hypochlorite solutions, phosphoric acid; and the sulfite liquors and sulfurous acids used in the paper pulp industry.

**Key Words:** UNS S31600, SS316, 316SS, AISI 316, DIN 1.4401, DIN 1.4408, DIN X5CrNiMo17122, TGL 39672 X5CrNiMo1911, TGL 7143X5CrNiMo1811, ISO 2604-1 F62, ISO 2604-2 TS60, ISO 2604-2 TS61, ISO 2604-4 P60, ISO 2604-4 P61, ISO 4954 X5CrNiMo17122E, ISO 683/13 20, ISO 683/13 20a, ISO 6931 X5CrNiMo17122, JIS SUS 316

## Datasheet of Thermoplastic Polyurethane, Elastomer, Polyester Grade<sup>3</sup>

Physical Properties	Metric	English	Comments
Density	0.992 - 1.44 g/cc	0.0358 - 0.0520 lb/in <sup>3</sup>	Average value: 1.21 g/cc Grade Count:211
Viscosity	30 - 5500 cP	30 - 5500 cP	Average value: 915 cP Grade Count:21
Maximum Moisture Content	0.020 - 0.050	0.020 - 0.050	Average value: 0.0329 Grade Count:35
Linear Mold Shrinkage	0.0020 - 0.025 cm/cm	0.0020 - 0.025 in/in	Average value: 0.00748 cm/cm Grade Count:72
Linear Mold Shrinkage, Transverse	-0.00200 - 0.0090 cm/cm	-0.00200 - 0.0090 in/in	Average value: 0.00513 cm/cm Grade Count:12
Melt Flow	4.0 - 90 g/10 min	4.0 - 90 g/10 min	Average value: 31.9 g/10 min Grade Count:51

Mechanical Properties	Metric	English	Comments
Hardness, Shore A	40 - 98	40 - 98	Average value: 85.3 Grade Count:159
Hardness, Shore D	12 - 79	12 - 79	Average value: 49.5 Grade Count:122
Tensile Strength, Ultimate	1.35 - 72.1 MPa	196 - 10400 psi	Average value: 38.8 MPa Grade Count:205
Tensile Strength, Yield	1.10 - 66.4 MPa	160 - 9630 psi	Average value: 14.1 MPa Grade Count:181
Elongation at Break	10 - 1580 %	10 - 1580 %	Average value: 550 % Grade Count:211
Modulus of Elasticity	0.00300 - 0.870 GPa	0.435 - 126 ksi	Average value: 0.136 GPa Grade Count:32
Flexural Yield Strength	2.61 - 62.7 MPa	379 - 9100 psi	Average value: 24.2 MPa Grade Count:6
Flexural Modulus	0.0276 - 1.21 GPa	4.00 - 175 ksi	Average value: 0.223 GPa Grade Count:28
Resilience	30 - 60	30 - 60	Average value: 42.3 Grade Count:22
Rebound	25 - 57 %	25 - 57 %	Average value: 38.1 % Grade Count:45
Shear Modulus	0.0120 - 0.250 GPa	1.74 - 36.3 ksi	Average value: 0.102 GPa Grade Count:3
Izod Impact, Notched	0.849 - 5340 J/cm	1.59 - 10000 ft-lb/in	Average value: 3.88 J/cm Grade Count:6
Izod Impact, Unnotched	0.961 - 5340 J/cm	1.80 - 10000 ft-lb/in	Average value: 0.969 J/cm Grade Count:3
Tear Strength	17.5 - 285 kN/m	100 - 1630 pli	Average value: 113 kN/m Grade Count:187
Peel Strength	0.0400 - 7.20 kN/m	0.228 - 41.1 pli	Average value: 1.93 kN/m Grade Count:6
Graves Tear Strength	52.6 - 210 kN/m	300 - 1200 pli	Average value: 124 kN/m Grade Count:18
Taber Abrasion, mg/1000 Cycles	0.70 - 127	0.70 - 127	Average value: 34.3 Grade Count:85

<sup>3</sup> Source | <http://www.matweb.com/search/DataSheet.aspx?MatGUID=9f5318a1f93b403bbd5748abec70fac1>

Compression Set	12 - 90 %	12 - 90 %	Average value: 33.0 % Grade Count:92
Tensile Set	4.0 - 155 %	4.0 - 155 %	Average value: 52.7 % Grade Count:46

Electrical Properties	Metric	English	Comments
Electrical Resistivity	1.00e+10 - 1.00e+13 ohm-cm	1.00e+10 - 1.00e+13 ohm-cm	Average value: 3.37e+12 ohm-cm Grade Count:3
Surface Resistance	5.00e+8 - 1.00e+12 ohm	5.00e+8 - 1.00e+12 ohm	Average value: 2.78e+11 ohm Grade Count:4
Dielectric Constant	4.1 - 7.1	4.1 - 7.1	Average value: 5.73 Grade Count:3
Dielectric Strength	31.0 - 49.0 kV/mm	787 - 1240 kV/in	Average value: 42.7 kV/mm Grade Count:3
Dissipation Factor	0.024 - 0.20	0.024 - 0.20	Average value: 0.0557 Grade Count:3
Comparative Tracking Index	600 V	600 V	Average value: 600 V Grade Count:6

Thermal Properties	Metric	English	Comments
CTE, linear	117 - 171 $\mu\text{m/m-}^{\circ}\text{C}$	65.0 - 95.0 $\mu\text{in/in-}^{\circ}\text{F}$	Average value: 150 $\mu\text{m/m-}^{\circ}\text{C}$ Grade Count:15
Melting Point	100 - 230 $^{\circ}\text{C}$	212 - 446 $^{\circ}\text{F}$	Average value: 170 $^{\circ}\text{C}$ Grade Count:43
Vicat Softening Point	35.0 - 165 $^{\circ}\text{C}$	95.0 - 329 $^{\circ}\text{F}$	Average value: 103 $^{\circ}\text{C}$ Grade Count:94
Brittleness Temperature	-70.0 - -50.0 $^{\circ}\text{C}$	-94.0 - -58.0 $^{\circ}\text{F}$	Average value: -68.4 $^{\circ}\text{C}$ Grade Count:16
Glass Transition Temp, Tg	-47.0 - 120 $^{\circ}\text{C}$	-52.6 - 248 $^{\circ}\text{F}$	Average value: -22.9 $^{\circ}\text{C}$ Grade Count:39
Transformation Temperature	-27.8 - -17.2 $^{\circ}\text{C}$	-18.0 - 1.00 $^{\circ}\text{F}$	Average value: -22.0 $^{\circ}\text{C}$ Grade Count:3
Clash Berg Stiffness Temperature	-40.0 - -5.00 $^{\circ}\text{C}$	-40.0 - 23.0 $^{\circ}\text{F}$	Average value: -26.4 $^{\circ}\text{C}$ Grade Count:6
Flammability, UL94	HB	HB	Grade Count:3
Ring & Ball Softening Point	161 - 179 $^{\circ}\text{C}$	322 - 354 $^{\circ}\text{F}$	Average value: 170 $^{\circ}\text{C}$ Grade Count:3

Optical Properties	Metric	English	Comments
Transmission, Visible	90 %	90 %	Average value: 90.0 % Grade Count:12

Processing Properties	Metric	English	Comments
Processing Temperature	155 - 216 $^{\circ}\text{C}$	311 - 421 $^{\circ}\text{F}$	Average value: 195 $^{\circ}\text{C}$ Grade Count:24
Nozzle Temperature	160 - 299 $^{\circ}\text{C}$	320 - 570 $^{\circ}\text{F}$	Average value: 199 $^{\circ}\text{C}$ Grade Count:75
Adapter Temperature	175 - 215 $^{\circ}\text{C}$	347 - 419 $^{\circ}\text{F}$	Average value: 193 $^{\circ}\text{C}$ Grade Count:43
Die Temperature	145 - 215 $^{\circ}\text{C}$	293 - 419 $^{\circ}\text{F}$	Average value: 194 $^{\circ}\text{C}$ Grade Count:56
Melt Temperature	120 - 238 $^{\circ}\text{C}$	248 - 460 $^{\circ}\text{F}$	Average value: 192 $^{\circ}\text{C}$ Grade

			Count:108
Head Temperature	170 - 210 °C	338 - 410 °F	Average value: 195 °C Grade Count:10
Mold Temperature	16.0 - 70.0 °C	60.8 - 158 °F	Average value: 36.2 °C Grade Count:51
Drying Temperature	54.0 - 110 °C	129 - 230 °F	Average value: 95.6 °C Grade Count:58
Moisture Content	0.010 - 0.10 %	0.010 - 0.10 %	Average value: 0.0425 % Grade Count:20
Dew Point	-40.0 - -30.0 °C	-40.0 - -22.0 °F	Average value: -35.7 °C Grade Count:35
Injection Pressure	4.96 - 15000 MPa	720 - 2.18e+6 psi	Average value: 958 MPa Grade Count:13

## Datasheet of Mateck Sapphire<sup>4</sup>

Physical Properties	Metric	English	Comments
Density	3.98 g/cc	0.144 lb/in <sup>3</sup>	
a Lattice Constant	4.758 Å	4.758 Å	
c Lattice Constant	12.991 Å	12.991 Å	
Molecular Weight	101.96 g/mol	101.96 g/mol	

Mechanical Properties	Metric	English	Comments
Vickers Microhardness	1940	1940	MPa
	2200	2200	MPa
Hardness, Mohs	9.0	9.0	
Modulus of Elasticity	426.4 GPa	61850 ksi	parallel to c-axis
	462.6 GPa	67100 ksi	perpendicular to c-axis
Poissons Ratio	0.309	0.309	
Shear Modulus	144.3 GPa	20930 ksi	perpendicular to c-axis
	162.9 GPa	23630 ksi	parallel to c-axis

Thermal Properties	Metric	English	Comments
CTE, linear	3.24 - 5.66 µm/m-°C @Temperature -60.0 - 60.0 °C	1.80 - 3.14 µin/in-°F @Temperature - 76.0 - 140 °F	perpendicular to c-axis
Specific Heat Capacity	0.761 J/g-°C	0.182 BTU/lb-°F	
Thermal Conductivity	23.1 W/m-K @Temperature 46.0 °C	160 BTU-in/hr- ft <sup>2</sup> -°F @Temperature 115 °F	parallel to c-axis
	25.2 W/m-K @Temperature 46.0 °C	175 BTU-in/hr- ft <sup>2</sup> -°F @Temperature 115 °F	perpendicular to c-axis
Melting Point	2030 °C	3690 °F	

Optical Properties	Metric	English	Comments
Refractive Index	1.6679 @Wavelength 4000 nm	1.6679 @Wavelength 4000 nm	
	1.6748 @Wavelength 4000 nm	1.6748 @Wavelength 4000 nm	
	1.692 @Wavelength 3000 nm	1.692 @Wavelength 3000 nm	
	1.7015 @Wavelength 3000 nm	1.7015 @Wavelength 3000 nm	
	1.746 @Wavelength 1000 nm	1.746 @Wavelength 1000 nm	
	1.7545 @Wavelength 1000 nm	1.7545 @Wavelength 1000 nm	
	1.7771 @Wavelength 546.1 nm	1.7771 @Wavelength 546.1 nm	at ne

<sup>4</sup> Source | <http://www.matweb.com/search/DataSheet.aspx?MatGUID=a188c3ef359945f7a6c04b9aadb0f42e>

Transmission, Visible	97 % @Wavelength 500 nm	97 % @Wavelength 500 nm	Internal Transmittance
IR Transmittance	45 % @Wavelength 5000 nm	45 % @Wavelength 5000 nm	Internal Transmittance
	97 % @Wavelength 1000 nm	97 % @Wavelength 1000 nm	Internal Transmittance
	97 % @Wavelength 3000 nm	97 % @Wavelength 3000 nm	Internal Transmittance
UV Transmittance	79 % @Wavelength 200 nm	79 % @Wavelength 200 nm	Internal Transmittance

#### Descriptive Properties

Cleavability	(1011) (1120)	imperfect
Constants of Elastic Compliance (Pa <sup>-1</sup> )	2.2E-12	S33
	2.3E-12	S11
	4E-13	S13
	5E-13	S14
	-6.8E-12	S44
	-7E-13	S12
Symmetry Class	3m	
Syngony	tetragon	
Thermal Coefficient of Refractive Index	8.8E-6 to 1.28E-5	β <sub>0</sub> at 3.39 microns for ±60°C
	9.9E-6 to 1.39E-5	β <sub>e</sub> at 3.39 microns for ±60°C
Thermal Stability, °C	162±8	
Transmission Range (microns)	0.17 - 5	